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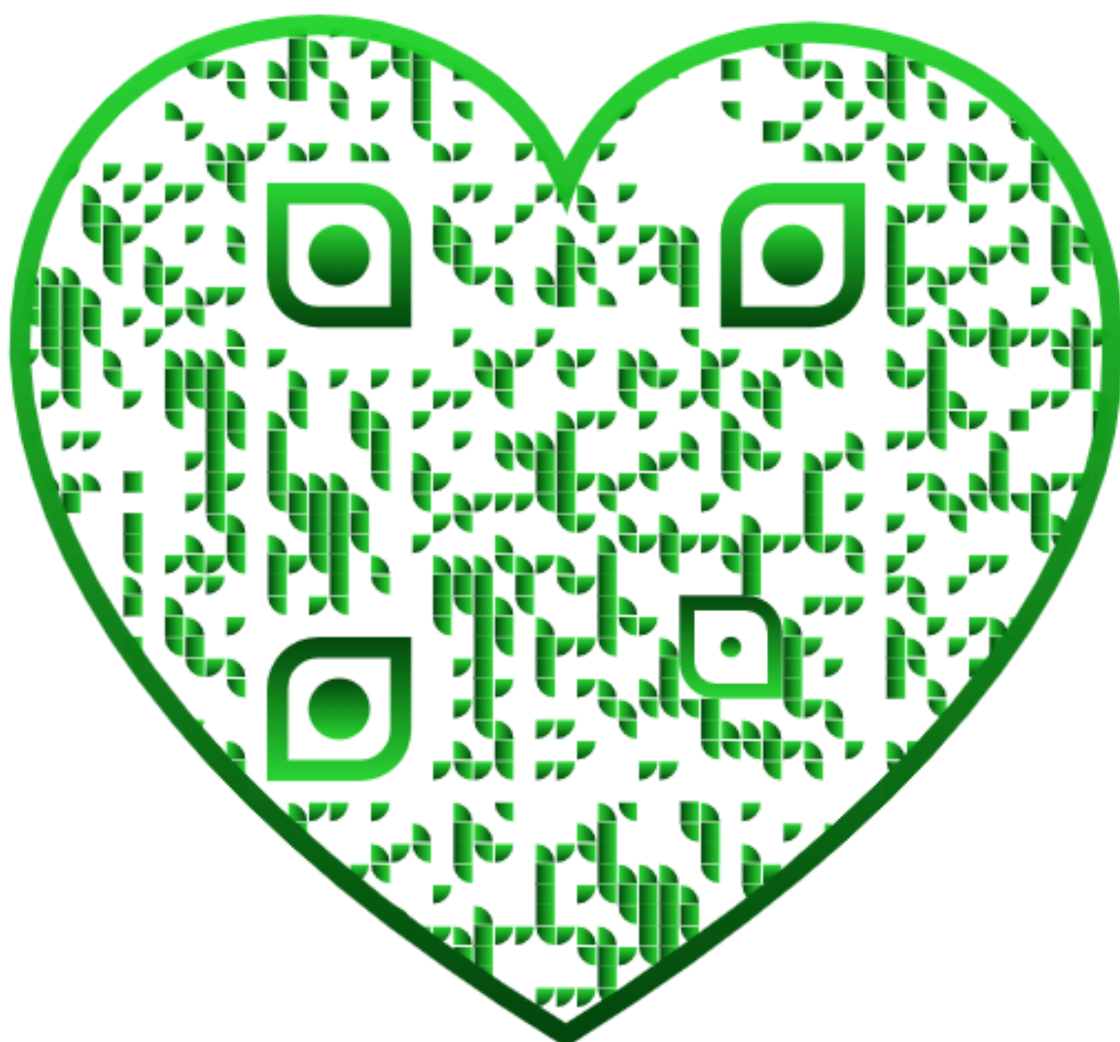
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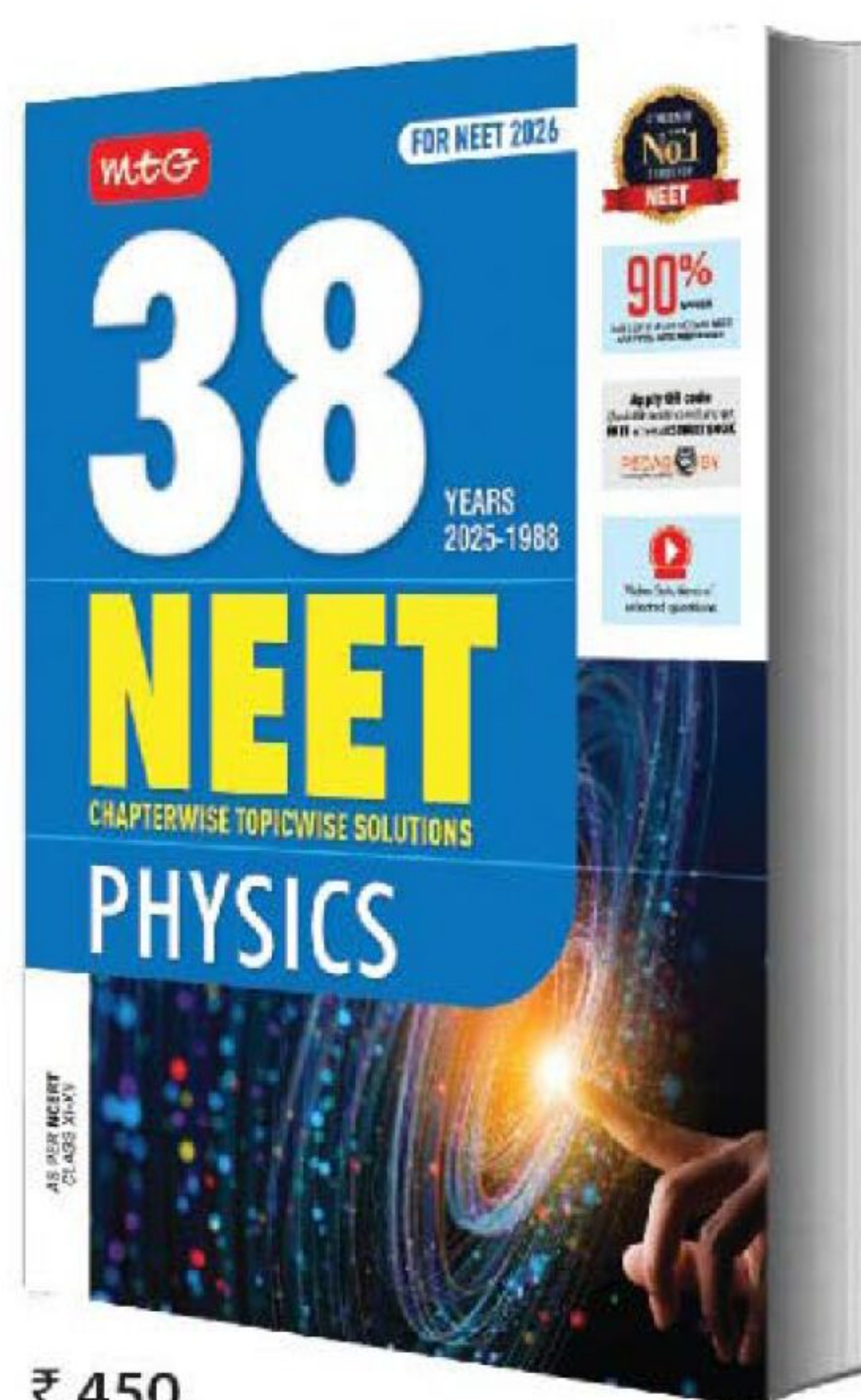
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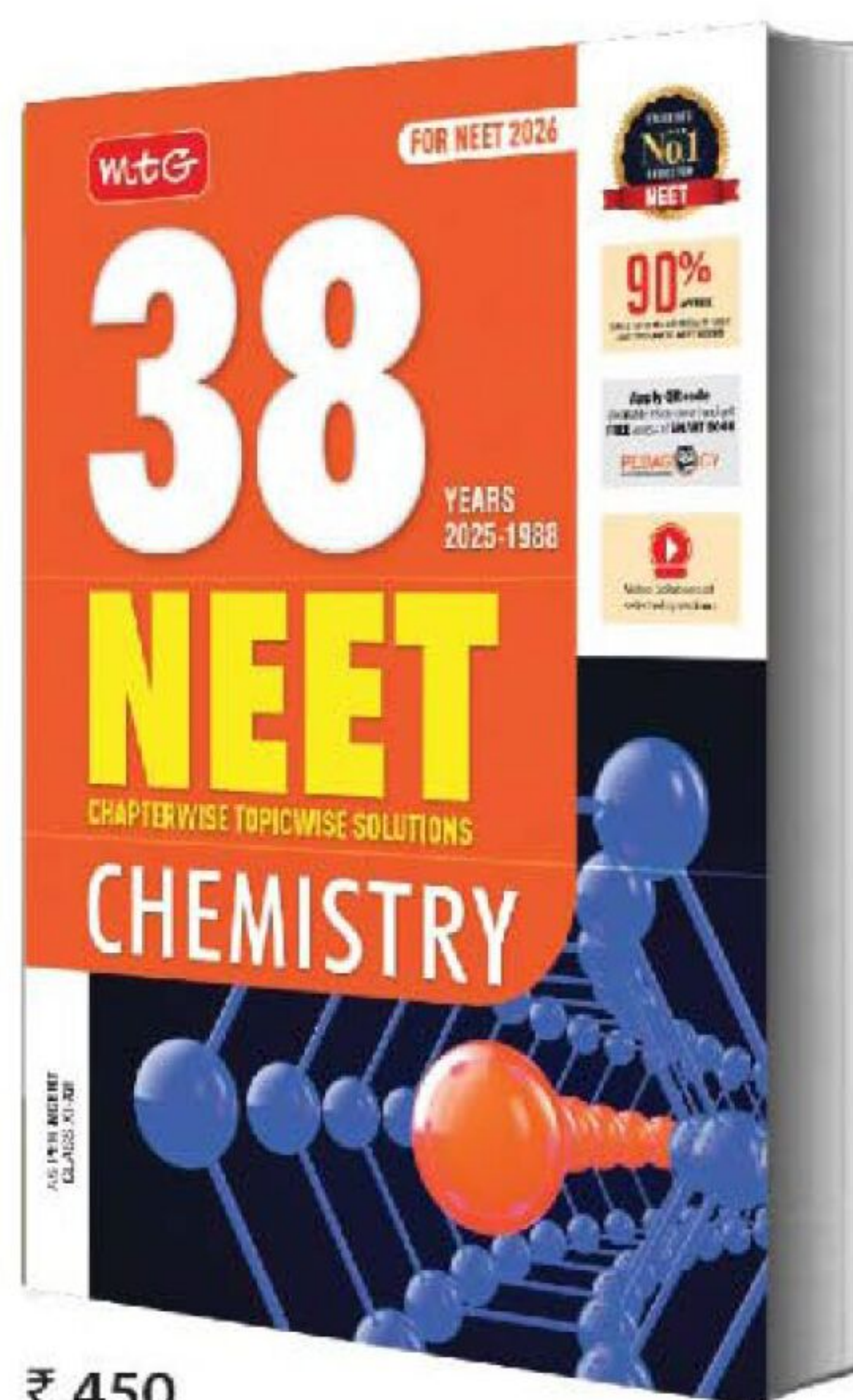
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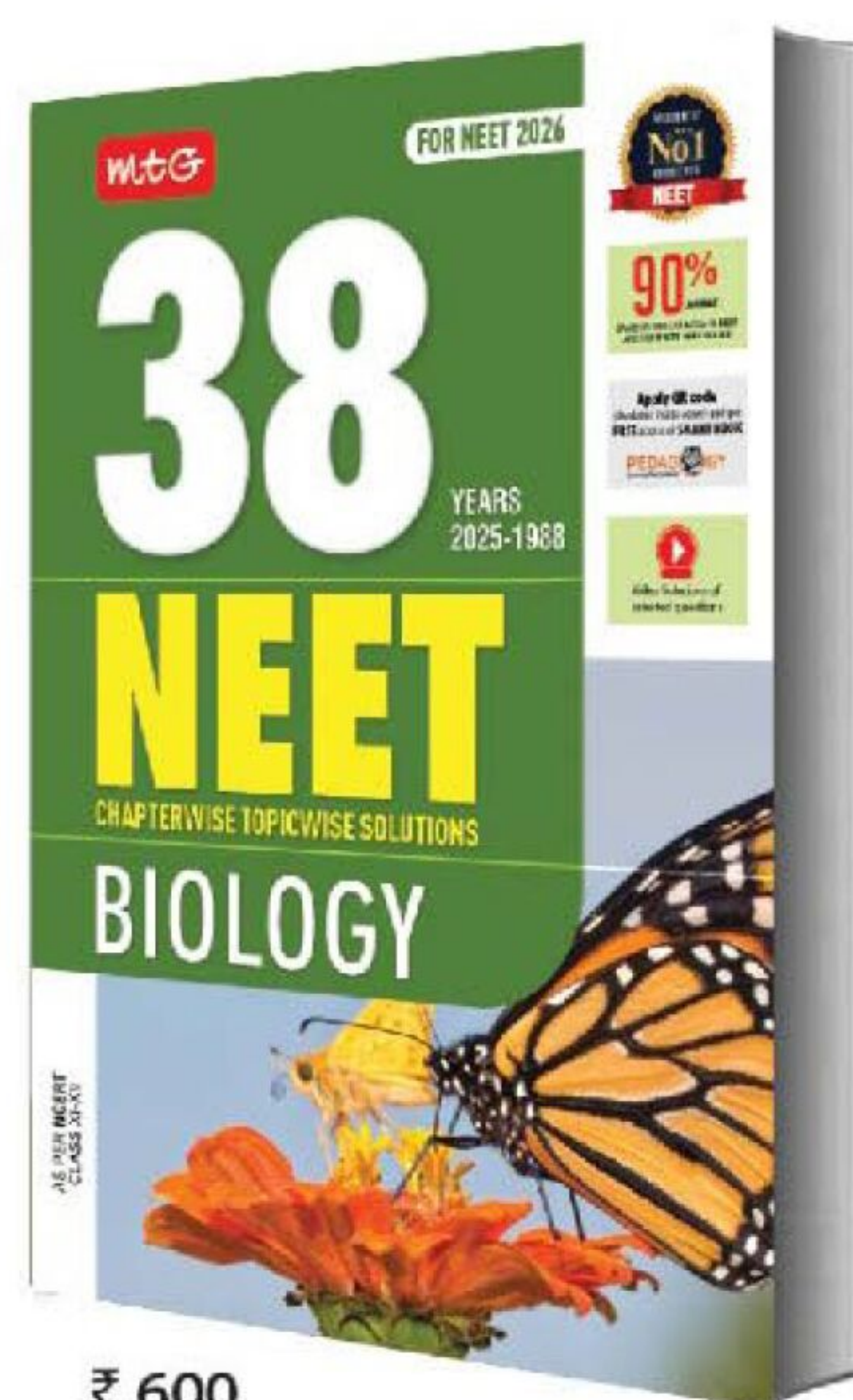
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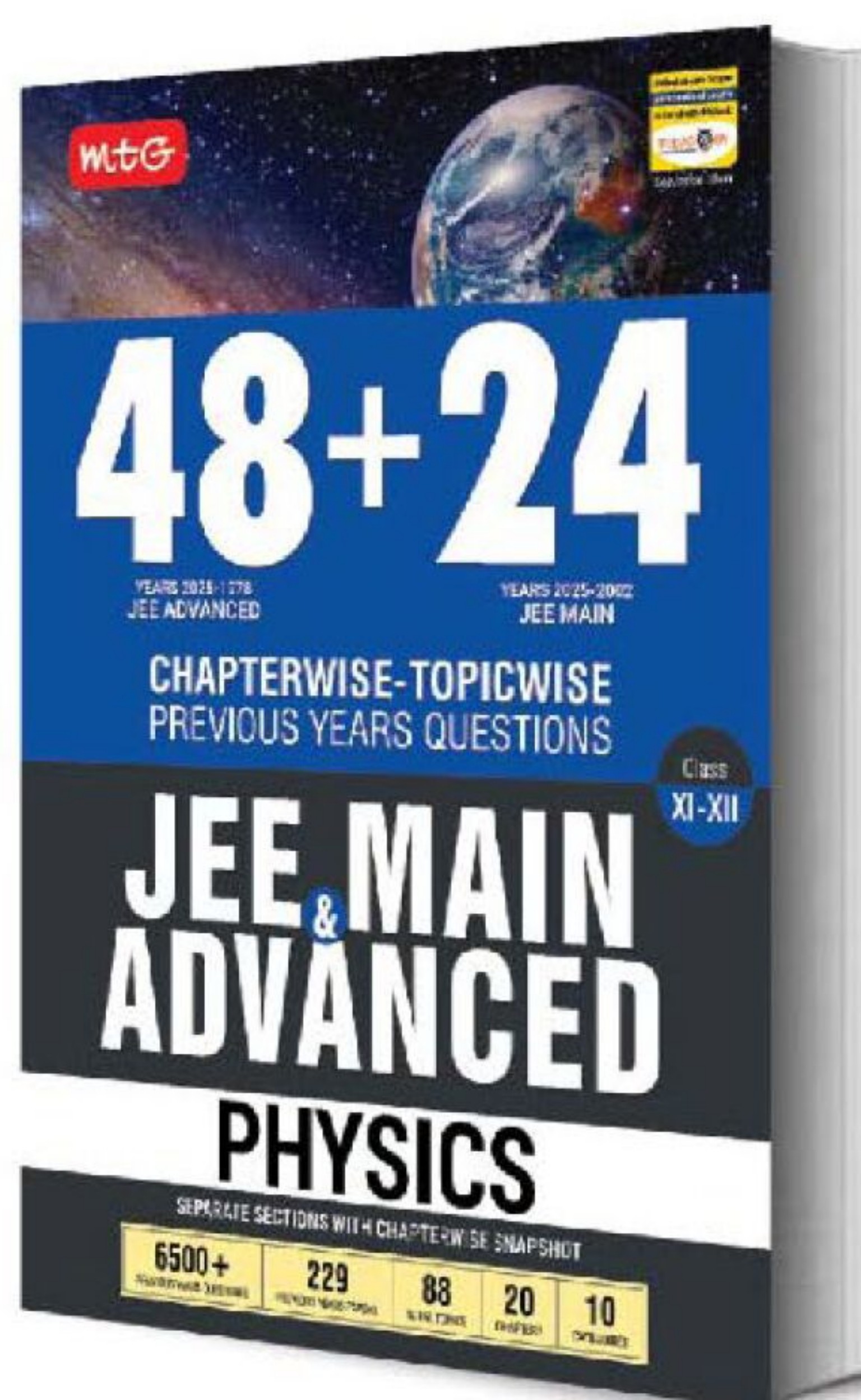
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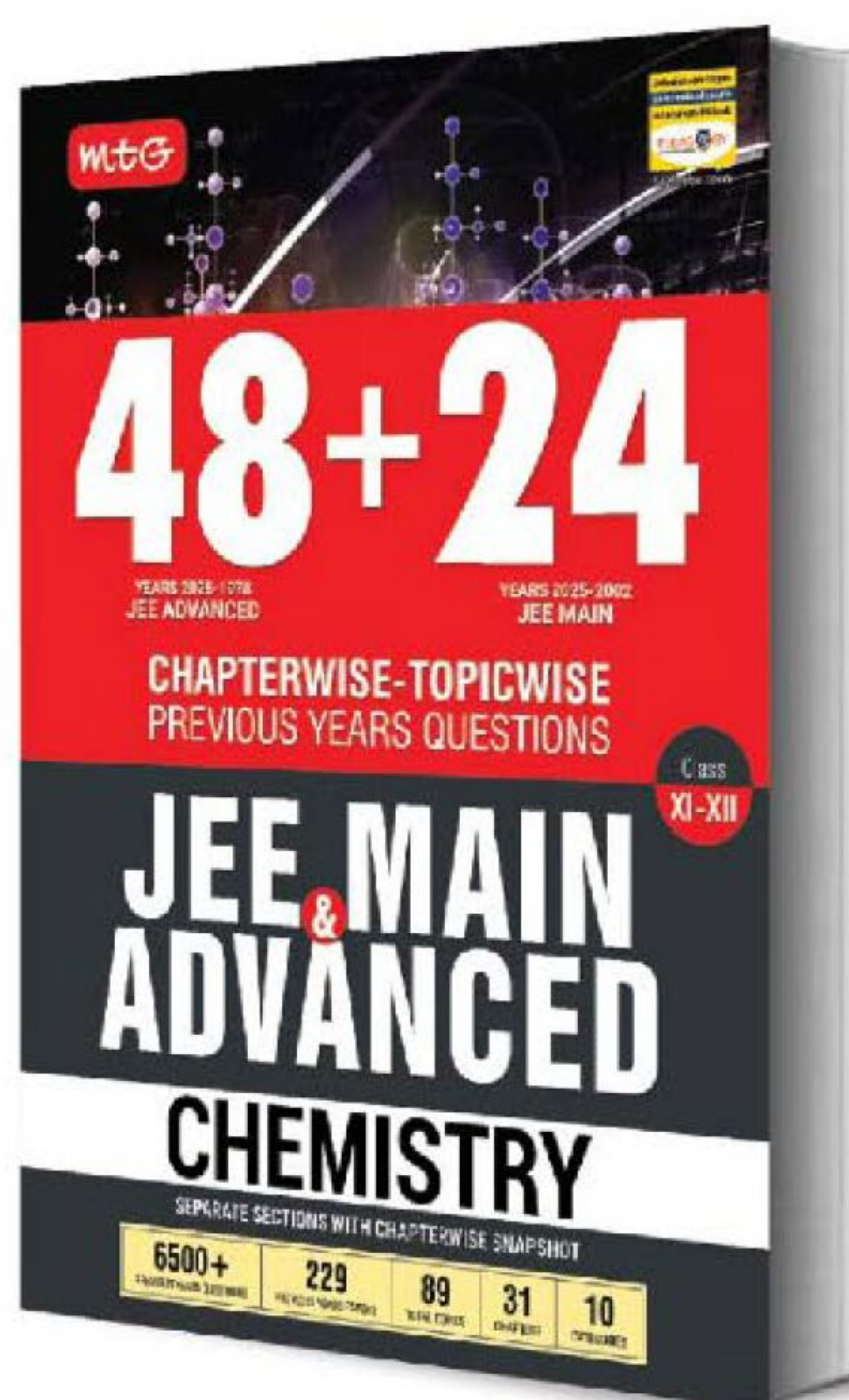
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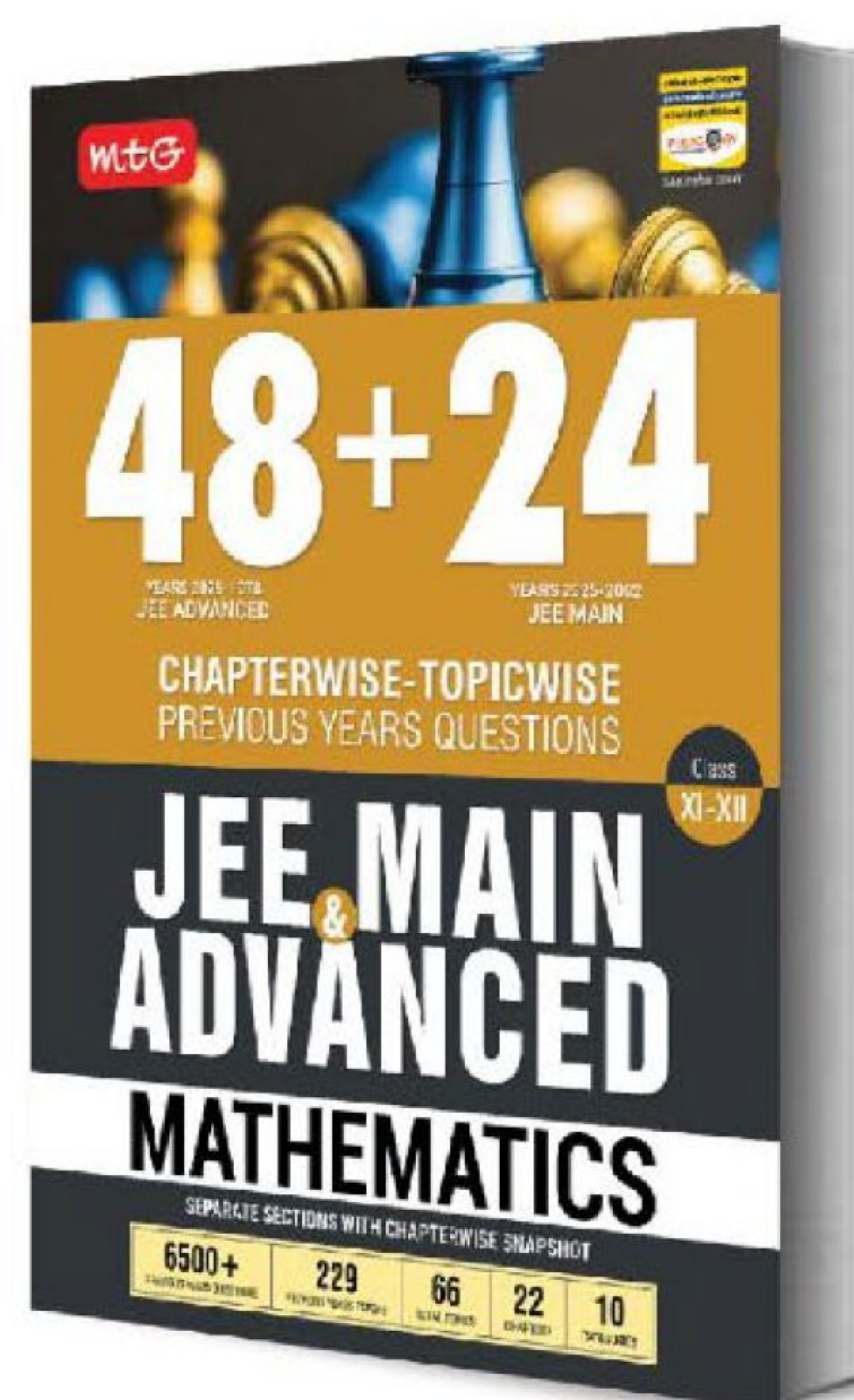
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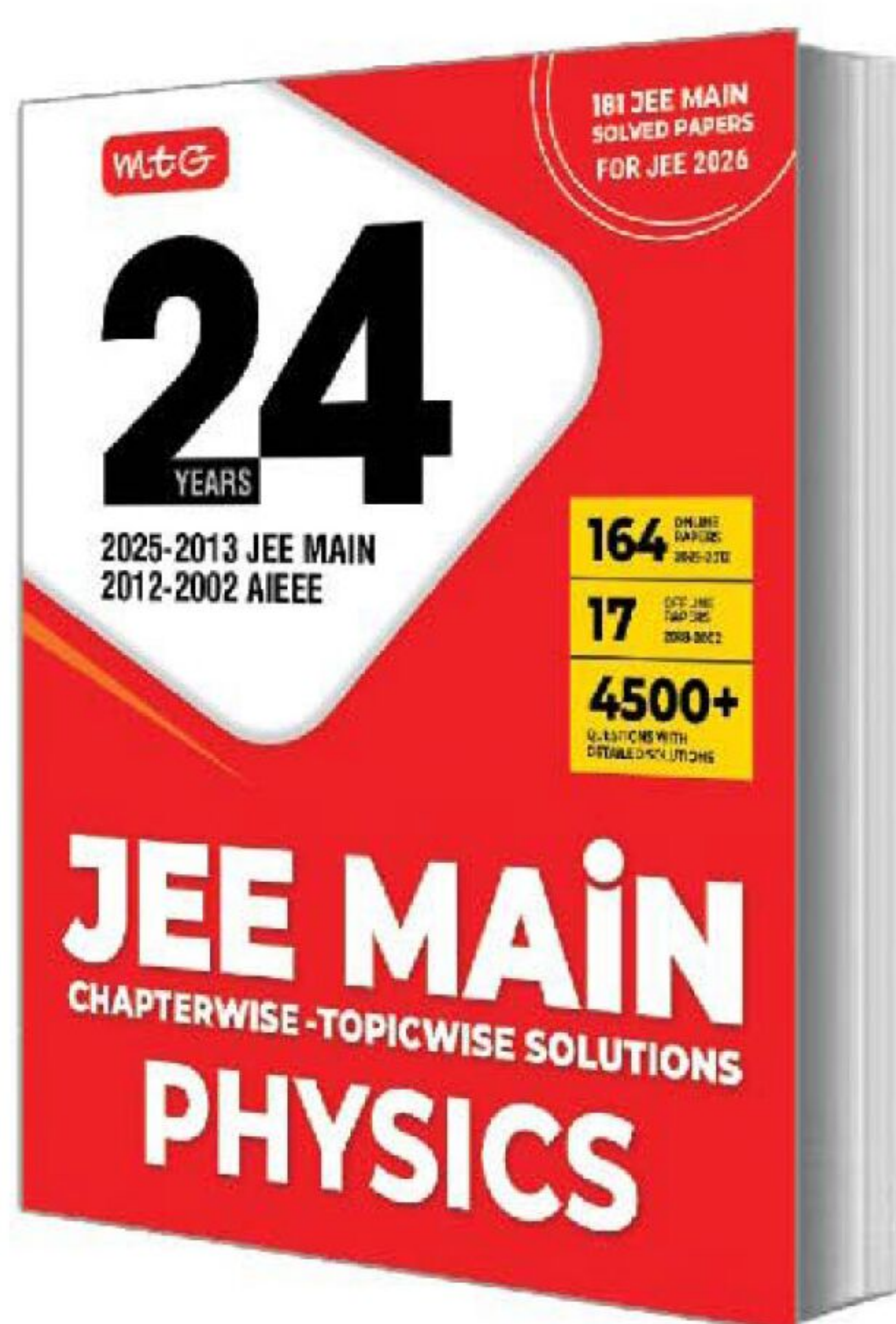


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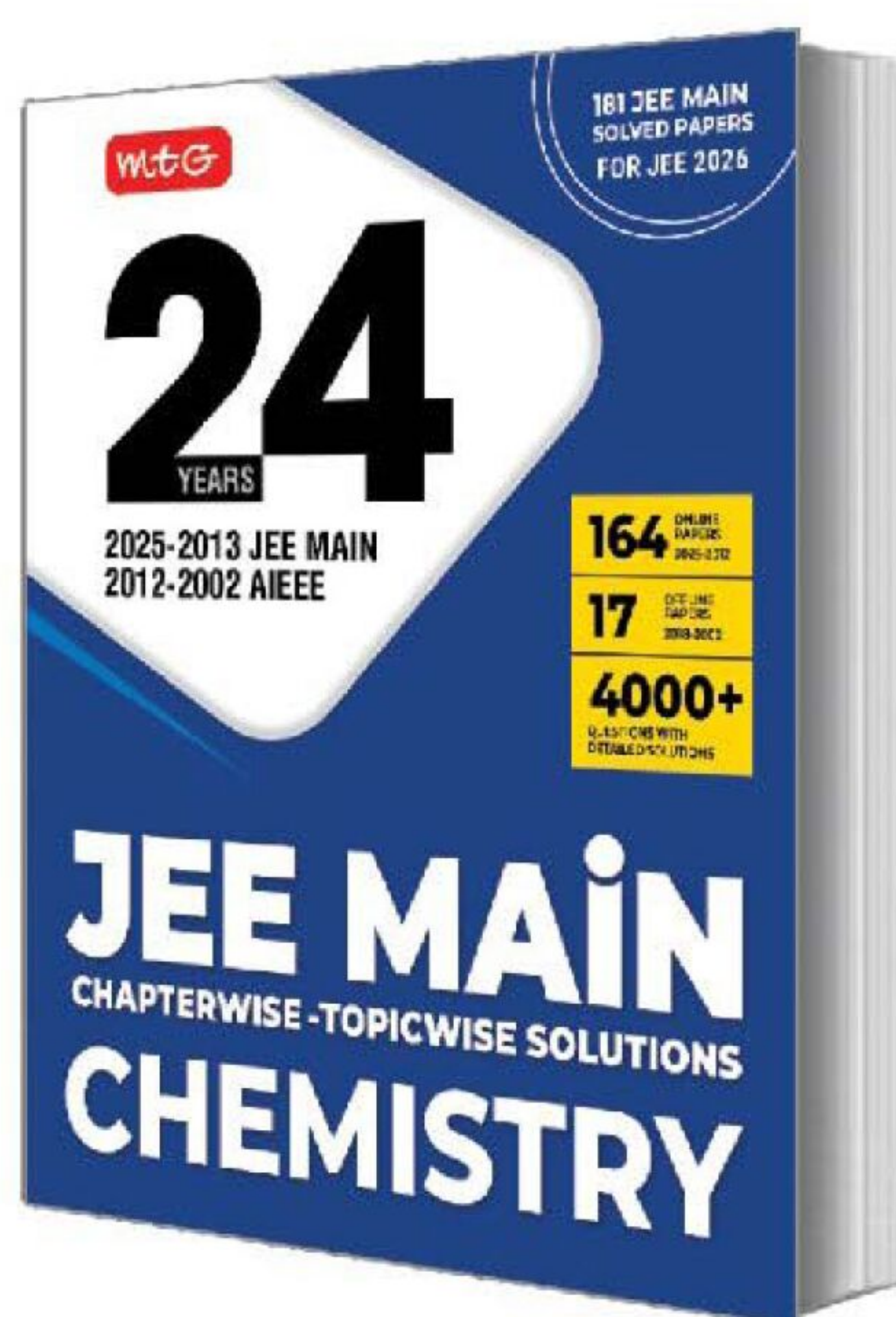


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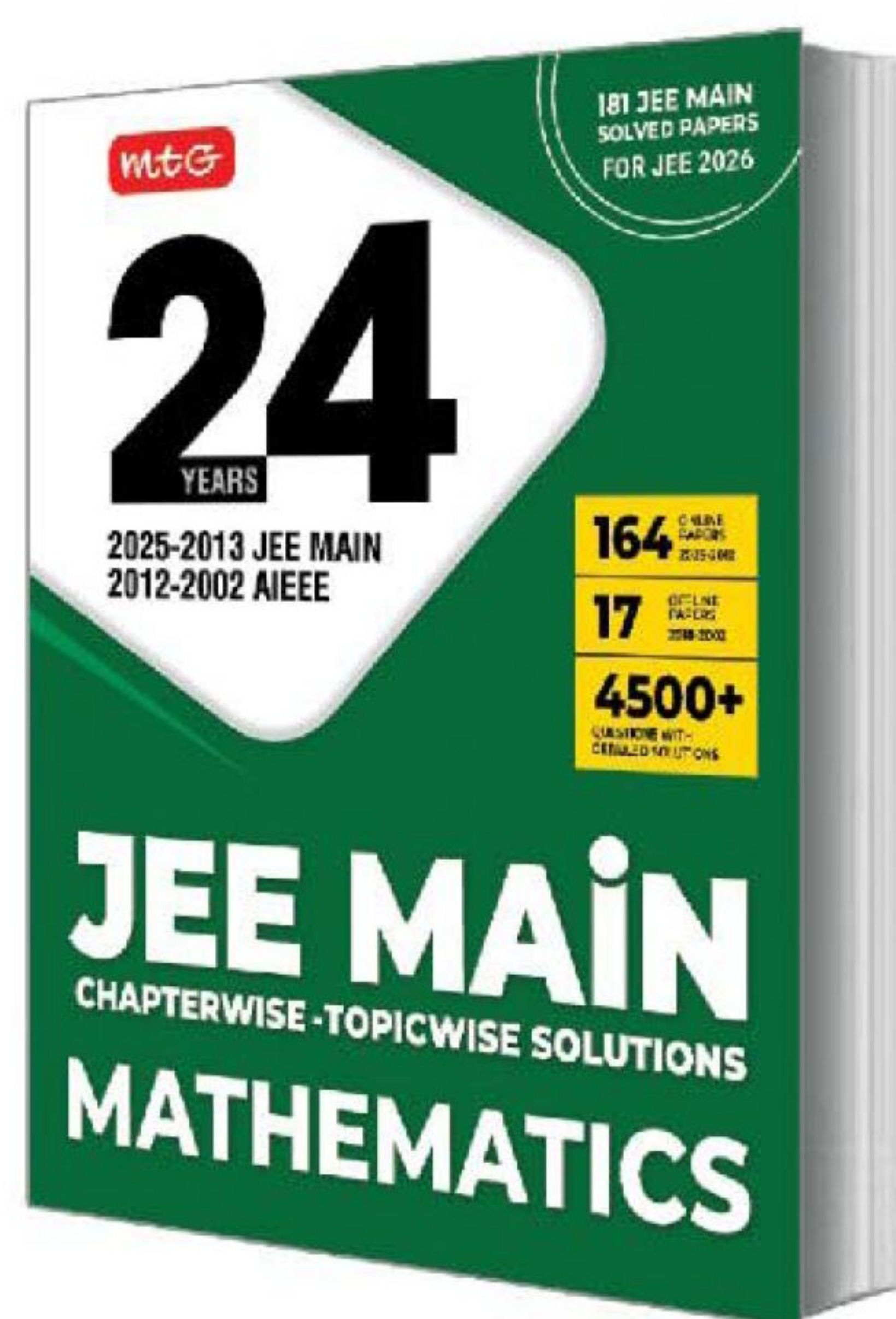
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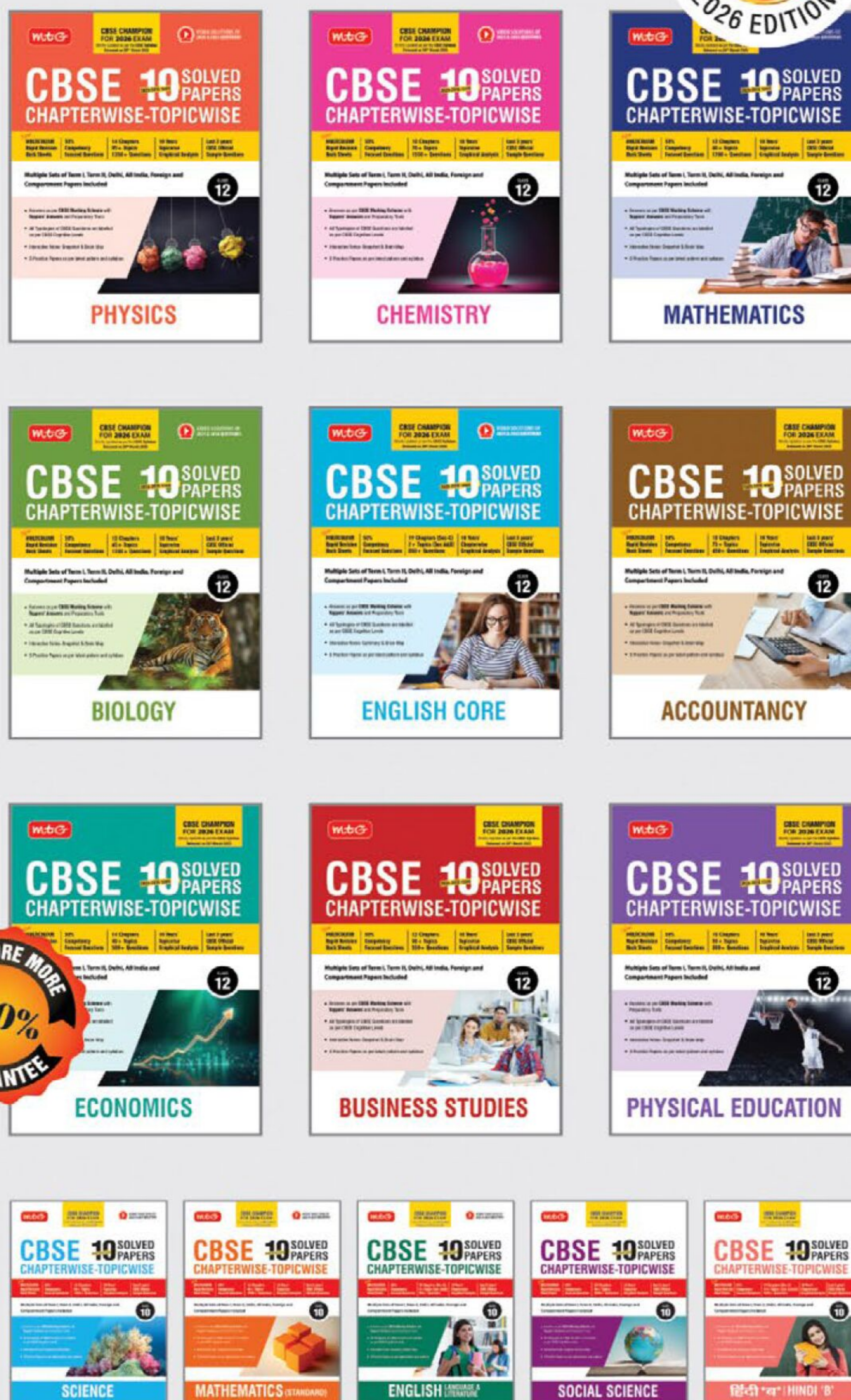
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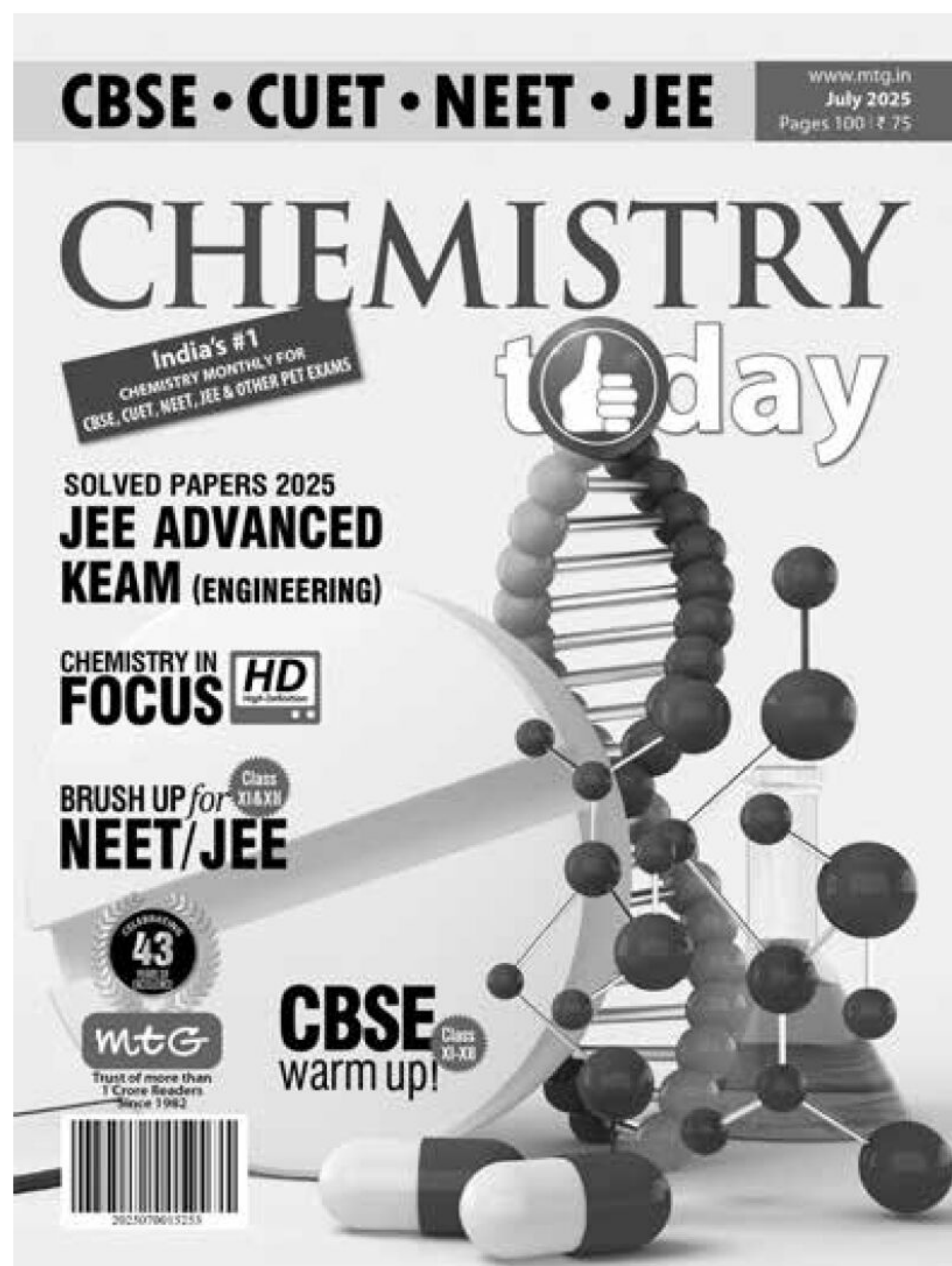
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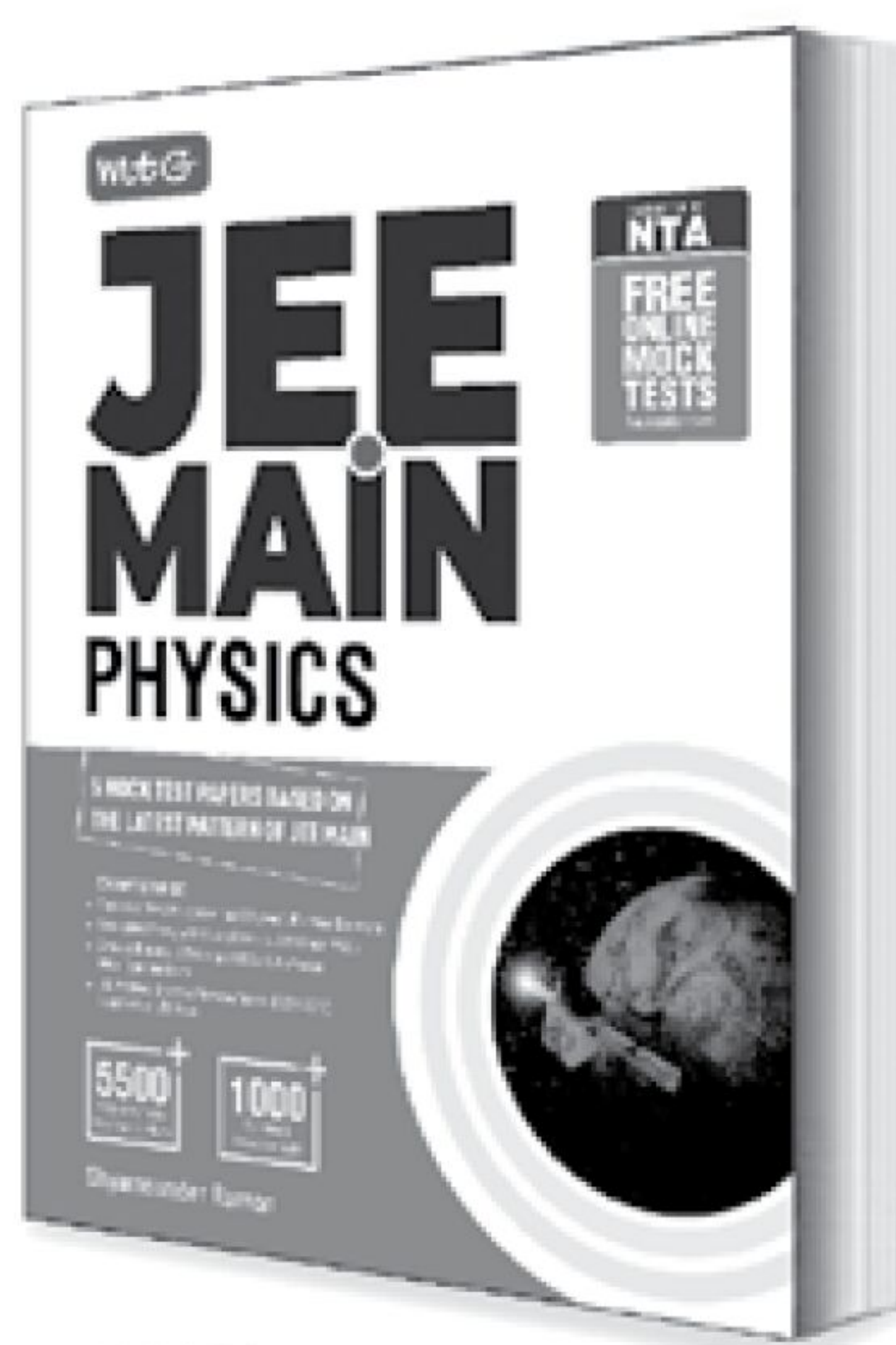
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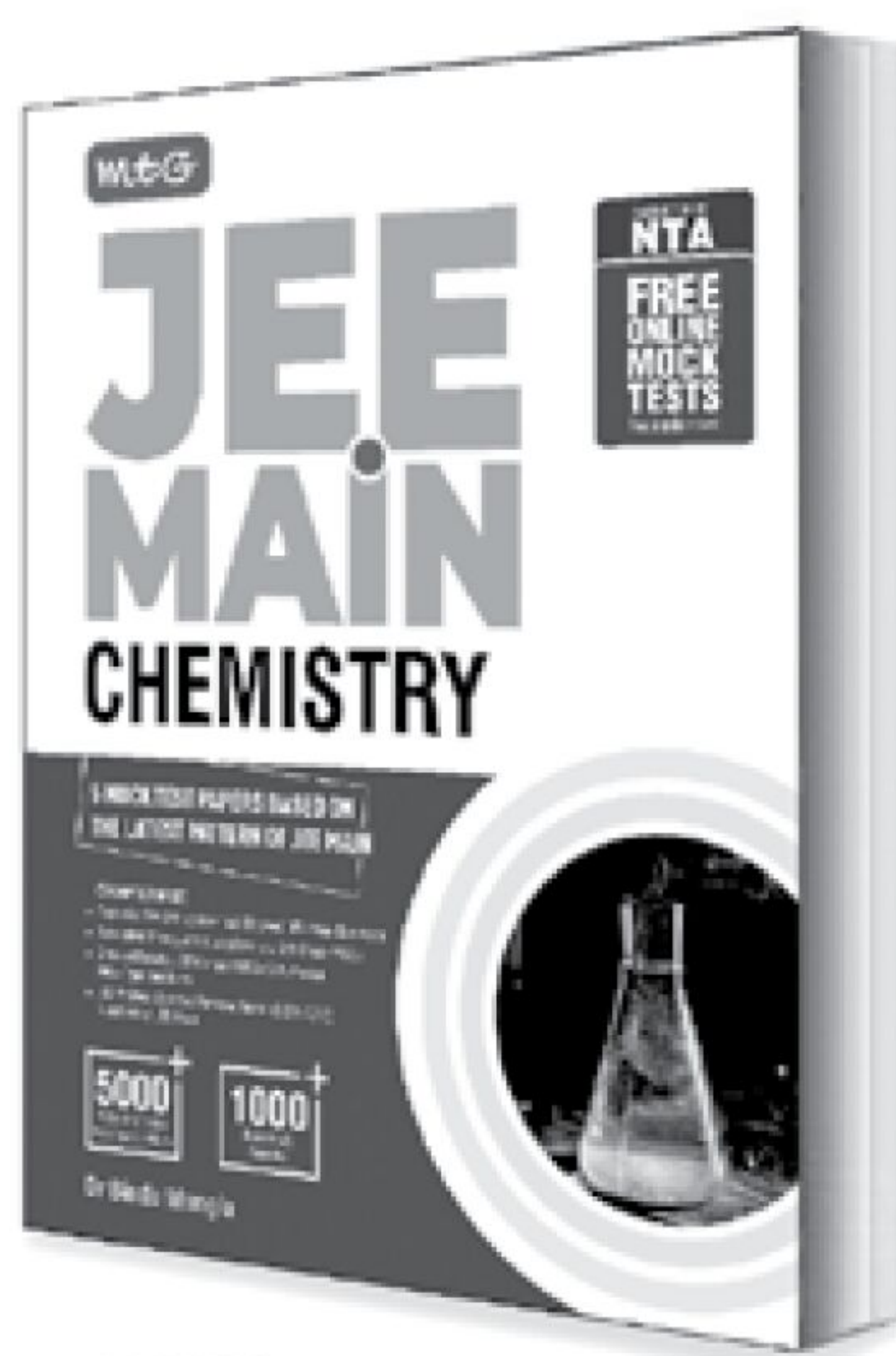
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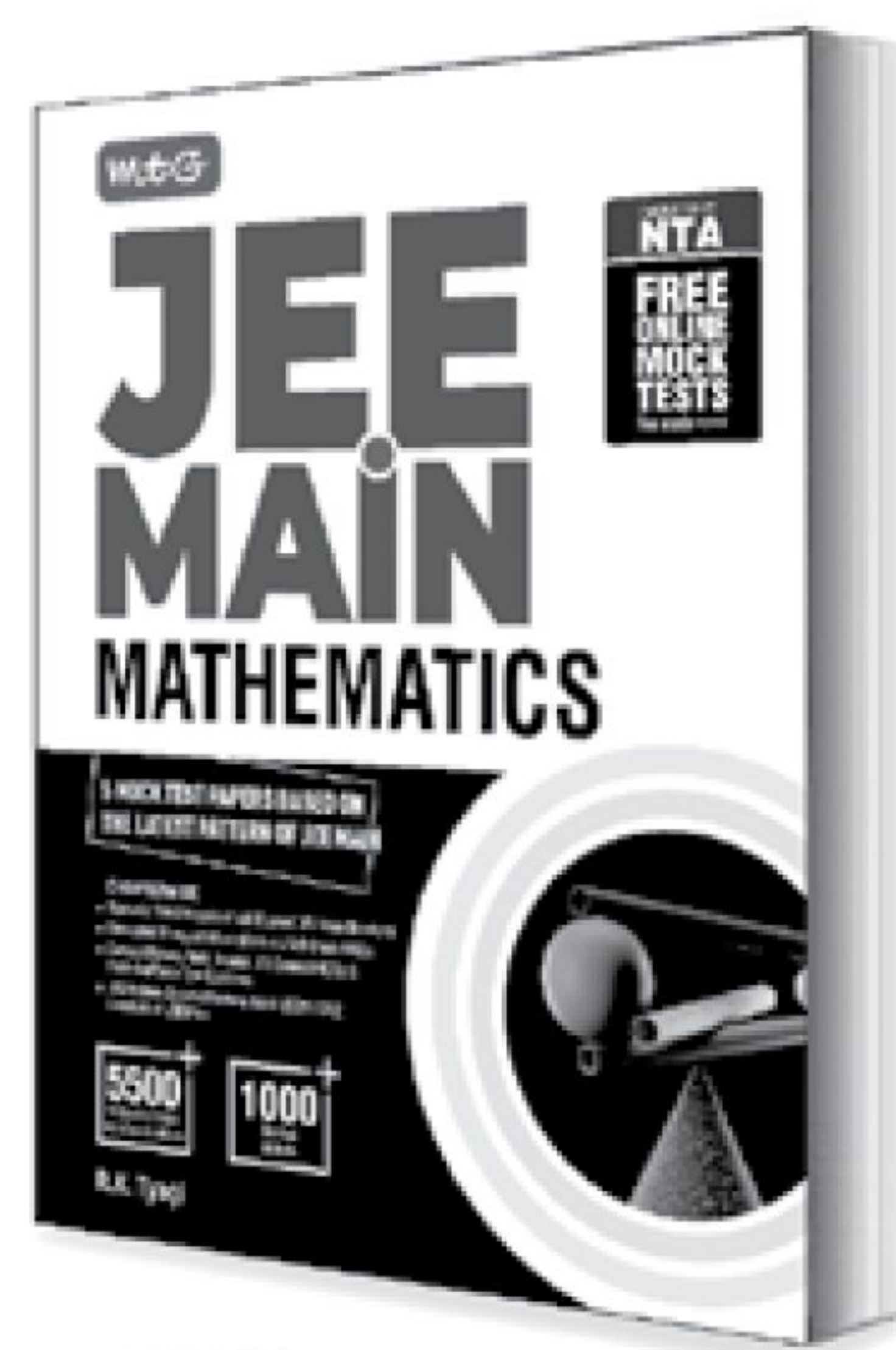
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JEE 2025

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PAPER-I

SECTION 1 (MAXIMUM MARKS : 12)

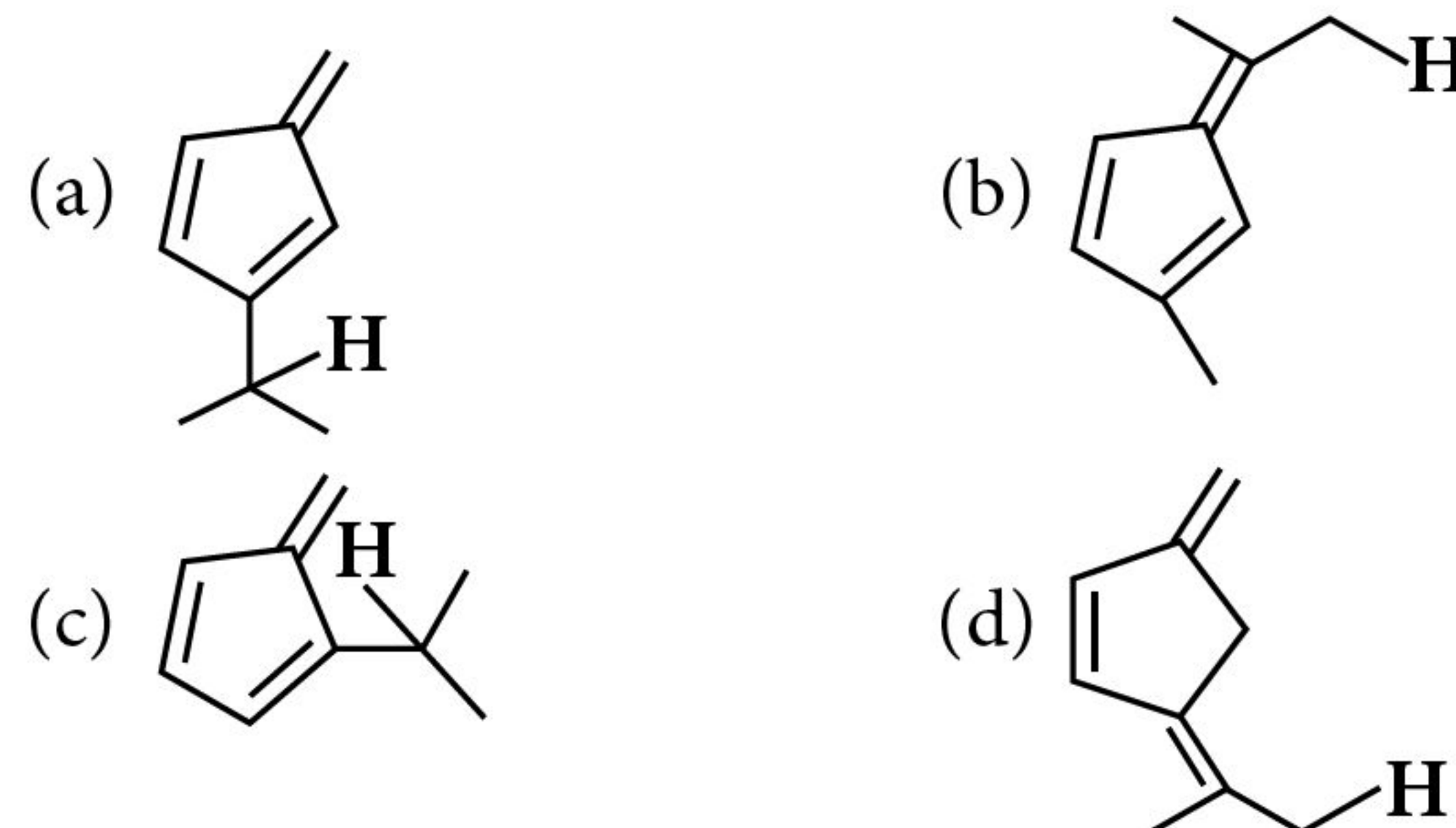
- This section contains FOUR (04) questions.
- Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If ONLY the correct option is chosen;

Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered);

Negative Marks : -1 In all other cases.

- The heating of NH_4NO_2 at $60-70^\circ\text{C}$ and NH_4NO_3 at $200-250^\circ\text{C}$ is associated with the formation of nitrogen containing compounds X and Y, respectively. X and Y, respectively, are
 (a) N_2 and N_2O (b) NH_3 and NO_2
 (c) NO and N_2O (d) N_2 and NH_3
- The correct order of the wavelength maxima of the absorption band in the ultraviolet-visible region for the given complexes is
 (a) $[\text{Co}(\text{CN})_6]^{3-} < [\text{Co}(\text{NH}_3)_6]^{3+} < [\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+} < [\text{Co}(\text{NH}_3)_5(\text{Cl})]^{2+}$
 (b) $[\text{Co}(\text{NH}_3)_5(\text{Cl})]^{2+} < [\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+} < [\text{Co}(\text{NH}_3)_6]^{3+} < [\text{Co}(\text{CN})_6]^{3-}$
 (c) $[\text{Co}(\text{CN})_6]^{3-} < [\text{Co}(\text{NH}_3)_5(\text{Cl})]^{2+} < [\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+} < [\text{Co}(\text{NH}_3)_6]^{3+}$
 (d) $[\text{Co}(\text{NH}_3)_6]^{3+} < [\text{Co}(\text{CN})_6]^{3-} < [\text{Co}(\text{NH}_3)_5(\text{Cl})]^{2+} < [\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+}$
- One of the products formed from the reaction of permanganate ion with iodide ion in neutral aqueous medium is
 (a) I_2 (b) IO_3^- (c) IO_4^- (d) IO_2^-
- Consider the depicted hydrogen (H) in the hydrocarbons given below. The most acidic hydrogen (H) is



SECTION 2 (MAXIMUM MARKS : 12)

- This section contains THREE (03) questions.
- Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 ONLY if (all) the correct option(s) is(are) chosen;

Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;

Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;

Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option;

Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered);

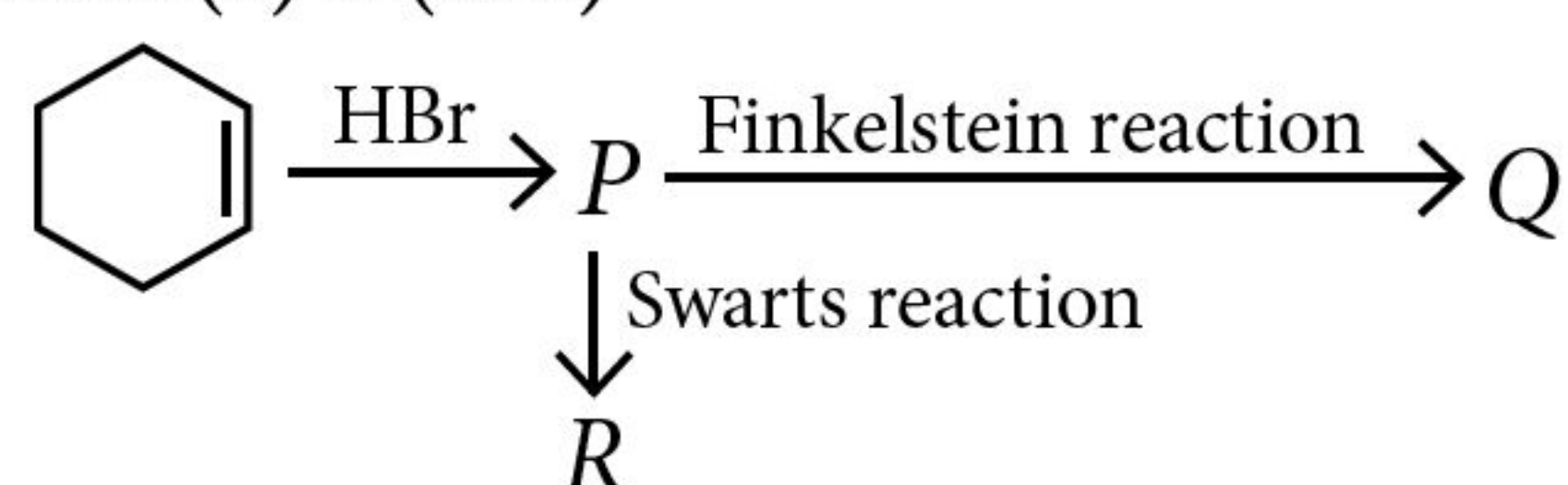
Negative Marks : -2 In all other cases.

- For example, in a question, if (a), (b) and (d) are the ONLY three options corresponding to correct answers, then choosing ONLY (a), (b) and (d) will get +4 marks; choosing ONLY (a) and (b) will get +2 marks; choosing ONLY (a) and (d) will get +2 marks; choosing ONLY (b) and (d) will get +2 marks; choosing ONLY (a) will get +1 mark; choosing ONLY (b) will get +1 mark; choosing ONLY (d) will get +1 mark; choosing no option (i.e., the question is unanswered) will get 0 marks; and choosing any other combination of options will get -2 marks.

5. Regarding the molecular orbital (MO) energy levels for homonuclear diatomic molecules, the incorrect statement(s) is(are)
- (a) bond order of Ne_2 is zero
 - (b) the highest occupied molecular orbital (HOMO) of F_2 is σ -type
 - (c) bond energy of O_2^+ is smaller than the bond energy of O_2
 - (d) bond length of Li_2 is larger than the bond length of B_2 .

6. The pair(s) of diamagnetic ions is(are)
- (a) La^{3+} , Ce^{4+}
 - (b) Yb^{2+} , Lu^{3+}
 - (c) La^{2+} , Ce^{3+}
 - (d) Yb^{3+} , Lu^{2+}

7. For the reaction sequence given below, the correct statement(s) is(are)



(In the options, X is any atom other than carbon and hydrogen, and it is different in P, Q and R)

- (a) C–X bond length in P, Q and R follows the order $Q > R > P$.
- (b) C–X bond enthalpy in P, Q and R follows the order $R > P > Q$.
- (c) Relative reactivity toward $\text{S}_{\text{N}}2$ reaction in P, Q and R follows the order $P > R > Q$.
- (d) $\text{p}K_{\text{a}}$ value of the conjugate acids of the leaving groups in P, Q and R follows the order $R > Q > P$.

SECTION 3 (MAXIMUM MARKS : 24)

- This section contains SIX (06) questions.
- The answer to each question is a NUMERICAL VALUE.
- For each question, enter the correct numerical value of the answer using the mouse and the on screen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 If ONLY the correct numerical value is entered in the designated place;

Zero Marks : 0 In all other cases.

8. In an electrochemical cell, dichromate ions in aqueous acidic medium are reduced to Cr^{3+} . The current (in amperes) that flows through the cell for 48.25 minutes to produce 1 mole of Cr^{3+} is _____. Use: 1 Faraday = 96500 C mol^{-1}

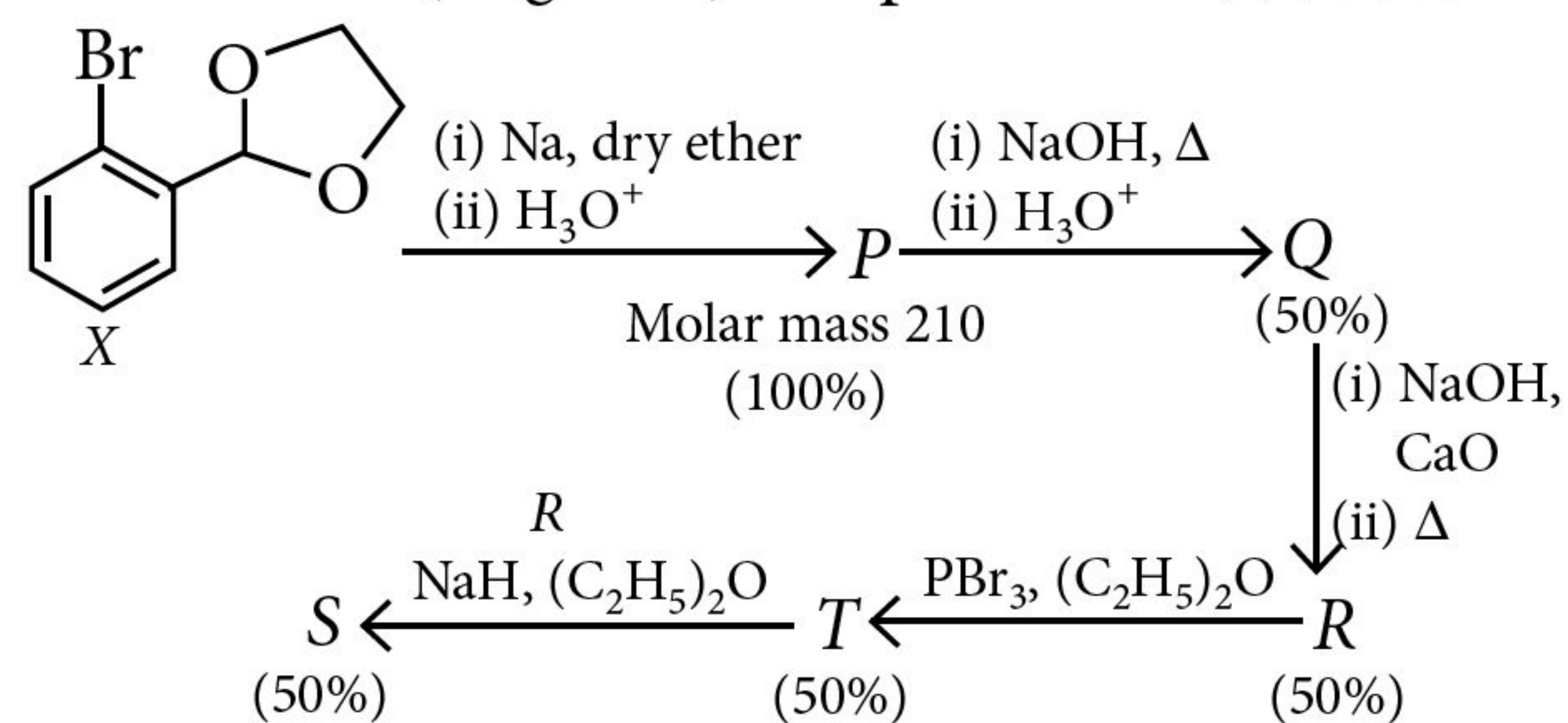
9. At 25°C , the concentration of H^+ ions in $1.00 \times 10^{-3} \text{ M}$ aqueous solution of a weak monobasic acid having acid dissociation constant (K_{a}) of 4.00×10^{-11} is $X \times 10^{-7} \text{ M}$. The value of X is _____. Use: Ionic product of water (K_{w}) = 1.00×10^{-14} at 25°C

10. Molar volume (V_{m}) of a van der Waals gas can be calculated by expressing the van der Waals equation as a cubic equation with V_{m} as the variable. The ratio (in mol dm^{-3}) of the coefficient of V_{m}^2 to the coefficient of V_{m} for a gas having van der Waals constants $a = 6.0 \text{ dm}^6 \text{ atm mol}^{-2}$ and $b = 0.060 \text{ dm}^3 \text{ mol}^{-1}$ at 300 K and 300 atm is _____. Use: Universal gas constant (R) = $0.082 \text{ dm}^3 \text{ atm mol}^{-1} \text{ K}^{-1}$

11. Considering ideal gas behavior, the expansion work done (in kJ) when 144 g of water is electrolyzed completely under constant pressure at 300 K is _____. Use: Universal gas constant (R) = $8.3 \text{ J K}^{-1} \text{ mol}^{-1}$; Atomic mass (in amu): H = 1, O = 16

12. The monomer (X) involved in the synthesis of Nylon 6, 6 gives positive carbylamine test. If 10 moles of X are analyzed using Dumas method, the amount (in grams) of nitrogen gas evolved is _____. Use: Atomic mass of N (in amu) = 14

13. The reaction sequence given below is carried out with 16 moles of X. The yield of the major product in each step is given below the product in parentheses. The amount (in grams) of S produced is _____.



Use: Atomic mass (in amu): H = 1, C = 12, O = 16, Br = 80

SECTION 4 (MAXIMUM MARKS : 12)

- This section contains THREE (03) Matching List Sets.
- Each set has ONE Multiple Choice Question.
- Each set has TWO lists : List-I and List-II.
- List-I has Four entries (P), (Q), (R) and (S) and List-II has Five entries (1), (2), (3), (4) and (5).
- FOUR options are given in each Multiple Choice Question based on List-I and List-II and ONLY ONE of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 ONLY if the option corresponding to the correct combination is chosen;

Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered);

Negative Marks : -1 In all other cases.

14. The correct match of the group reagents in List-I for precipitating the metal ion given in List-II from solutions, is

List-I		List-II	
(P)	Passing H_2S in the presence of NH_4OH	1.	Cu^{2+}
(Q)	$(\text{NH}_4)_2\text{CO}_3$ in the presence of NH_4OH	2.	Al^{3+}
(R)	NH_4OH in the presence of NH_4Cl	3.	Mn^{2+}
(S)	Passing H_2S in the presence of dilute HCl	4.	Ba^{2+}
		5.	Mg^{2+}

- (a) $\text{P} \rightarrow 3; \text{Q} \rightarrow 4; \text{R} \rightarrow 2; \text{S} \rightarrow 1$
 (b) $\text{P} \rightarrow 4; \text{Q} \rightarrow 2; \text{R} \rightarrow 3; \text{S} \rightarrow 1$
 (c) $\text{P} \rightarrow 3; \text{Q} \rightarrow 4; \text{R} \rightarrow 1; \text{S} \rightarrow 5$
 (d) $\text{P} \rightarrow 5; \text{Q} \rightarrow 3; \text{R} \rightarrow 2; \text{S} \rightarrow 4$
15. The major products obtained from the reactions in List-I are the reactants for the named reactions mentioned in List-II. Match each entry in List-I with the appropriate entry in List-II and choose the correct option.

List-I		List-II	
(P)	Stephen reaction	1.	Toluene $\xrightarrow[\text{(ii) } \text{H}_3\text{O}^+]{\text{(i) } \text{CrO}_2\text{Cl}_2/\text{CS}_2}$
(Q)	Sandmeyer reaction	2.	Benzoic acid $\xrightarrow[\text{(iii) } \text{P}_4\text{O}_{10}, \Delta]{\text{(i) } \text{PCl}_5, \text{(ii) } \text{NH}_3}$
(R)	Hoffmann bromamide degradation reaction	3.	Nitrobenzene $\xrightarrow[\text{(273-278 K), } \text{H}_2\text{O}]{\text{(i) } \text{Fe, HCl}, \text{(ii) } \text{HCl, NaNO}_2}$
(S)	Cannizzaro reaction	4.	Toluene $\xrightarrow[\text{(iv) } \text{NH}_3]{\text{(i) } \text{Cl}_2/h\nu, \text{H}_2\text{O}, \text{(ii) } \text{Tollens' reagent}, \text{(iii) } \text{SO}_2\text{Cl}_2}$
		5.	Aniline $\xrightarrow[\text{(iii) aq. NaOH}]{\text{(i) } (\text{CH}_3\text{CO})_2\text{O, Pyridine}, \text{(ii) } \text{HNO}_3, \text{H}_2\text{SO}_4, 288 \text{ K}}$

- (a) $\text{P} \rightarrow 2; \text{Q} \rightarrow 4; \text{R} \rightarrow 1; \text{S} \rightarrow 3$
 (b) $\text{P} \rightarrow 2; \text{Q} \rightarrow 3; \text{R} \rightarrow 4; \text{S} \rightarrow 1$
 (c) $\text{P} \rightarrow 5; \text{Q} \rightarrow 3; \text{R} \rightarrow 4; \text{S} \rightarrow 2$
 (d) $\text{P} \rightarrow 5; \text{Q} \rightarrow 4; \text{R} \rightarrow 2; \text{S} \rightarrow 1$

16. Match the compounds in List-I with the appropriate observations in List-II and choose the correct option.

List-I		List-II	
(P)		1.	Reaction with phenyl diazonium salt gives yellow dye.
(Q)		2.	Reaction with ninhydrin gives purple color and it also reacts with FeCl_3 to give violet color.
(R)		3.	Reaction with glucose will give corresponding hydrazone.
(S)		4.	Lassaigne extract of the compound treated with dilute HCl followed by addition of aqueous FeCl_3 gives blood red color.
		5.	After complete hydrolysis, it will give ninhydrin test and it does not give positive phthalein dye test.

- (a) $\text{P} \rightarrow 1; \text{Q} \rightarrow 5; \text{R} \rightarrow 4; \text{S} \rightarrow 2$
 (b) $\text{P} \rightarrow 2; \text{Q} \rightarrow 5; \text{R} \rightarrow 1; \text{S} \rightarrow 3$
 (c) $\text{P} \rightarrow 5; \text{Q} \rightarrow 2; \text{R} \rightarrow 1; \text{S} \rightarrow 4$
 (d) $\text{P} \rightarrow 2; \text{Q} \rightarrow 1; \text{R} \rightarrow 5; \text{S} \rightarrow 3$

SECTION 1 (MAXIMUM MARKS : 12)

- This section contains FOUR (04) questions.
- Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If ONLY the correct option is chosen;

Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered);

Negative Marks : -1 In all other cases.

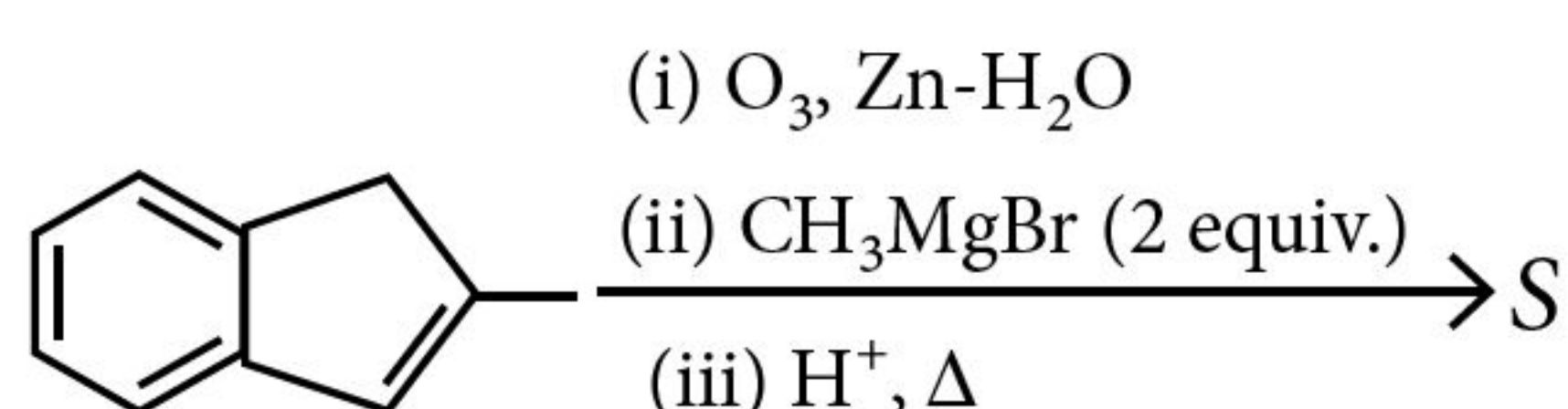
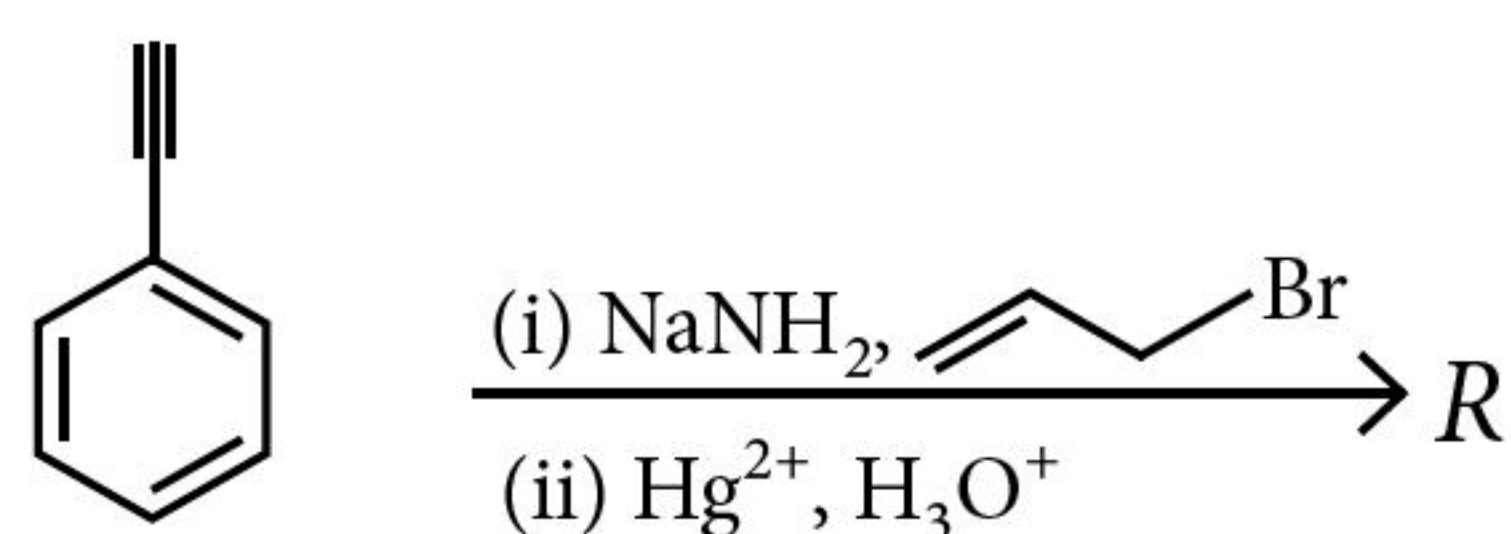
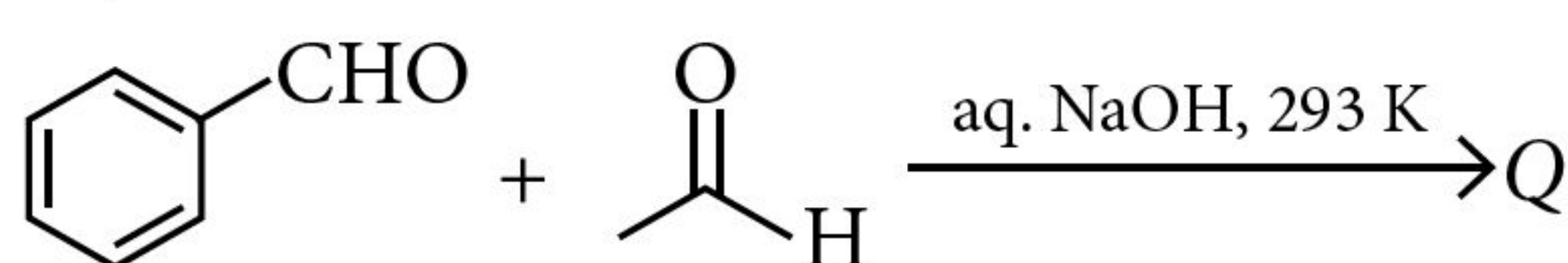
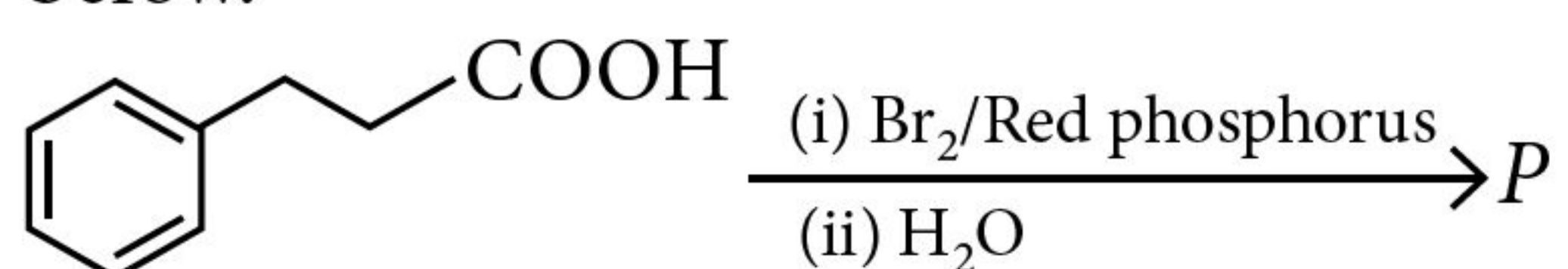
1. During sodium nitroprusside test of sulphide ion in an aqueous solution, one of the ligands coordinated to the metal ion is converted to

- (a) NOS^- (b) SCN^-
(c) SNO^- (d) NCS^-

2. The complete hydrolysis of ICl , ClF_3 and BrF_5 , respectively, gives

- (a) IO^- , ClO_2^- and BrO_3^-
(b) IO_3^- , ClO_2^- and BrO_3^-
(c) IO^- , ClO^- and BrO_2^-
(d) IO_3^- , ClO_4^- and BrO_2^-

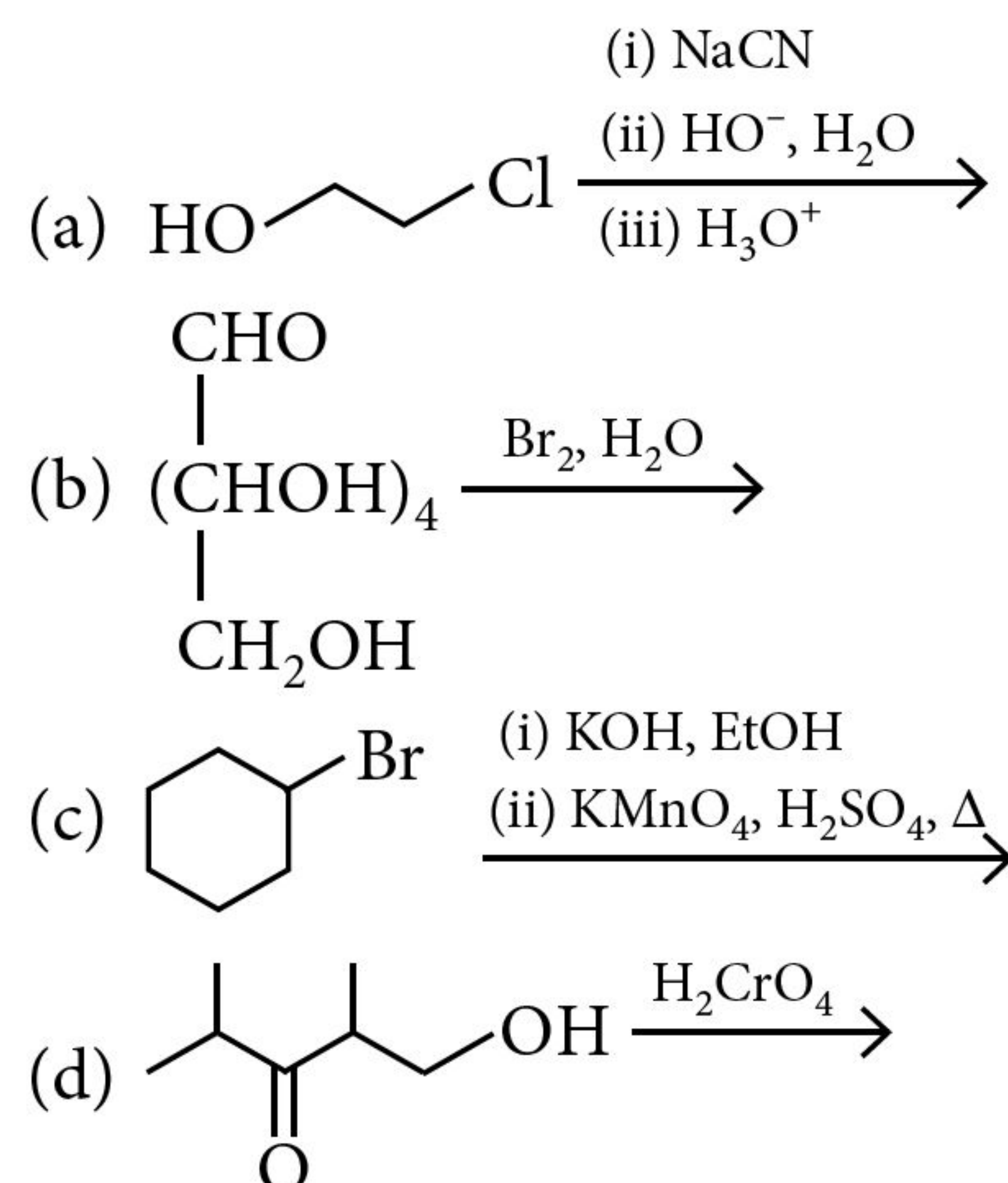
3. Monocyclic compounds P, Q, R and S are the major products formed in the reaction sequences given below.



The product having the highest number of unsaturated carbon atom(s) is

- (a) P (b) Q (c) R (d) S

4. The correct reaction/reaction sequence that would produce a dicarboxylic acid as the major product is



SECTION 2 (MAXIMUM MARKS : 16)

- This section contains FOUR (04) questions.
- Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 ONLY if (all) the correct option(s) is(are) chosen;

Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;

Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;

Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option;

Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);

Negative Marks : -2 In all other cases.

- For example, in a question, if (a), (b) and (d) are the ONLY three options corresponding to correct answers, then choosing ONLY (a), (b) and (d) will get +4 marks; choosing ONLY (a) and (b) will get +2 marks; choosing ONLY (a) and (d) will get +2 marks; choosing ONLY (b) and (d) will get +2 marks; choosing ONLY (a) will get +1 mark; choosing ONLY (b) will get +1 mark; choosing ONLY (d) will get +1 mark; choosing no option (i.e., the question is unanswered) will get 0 marks; and choosing any other combination of option will get -2 marks.

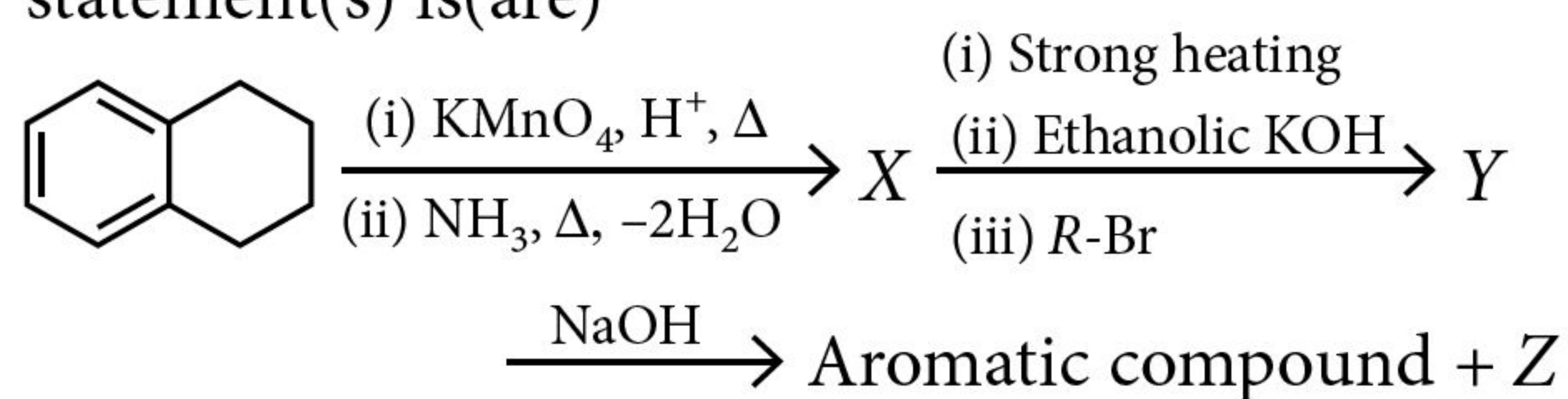
5. The correct statement(s) about intermolecular forces is(are)

- (a) The potential energy between two point charges approaches zero more rapidly than the potential energy between a point dipole and a point charge as the distance between them approaches infinity.
- (b) The average potential energy of two rotating polar molecules that are separated by a distance r has $1/r^3$ dependence.
- (c) The dipole-induced dipole average interaction energy is independent of temperature.
- (d) Nonpolar molecules attract one another even though neither has a permanent dipole moment.

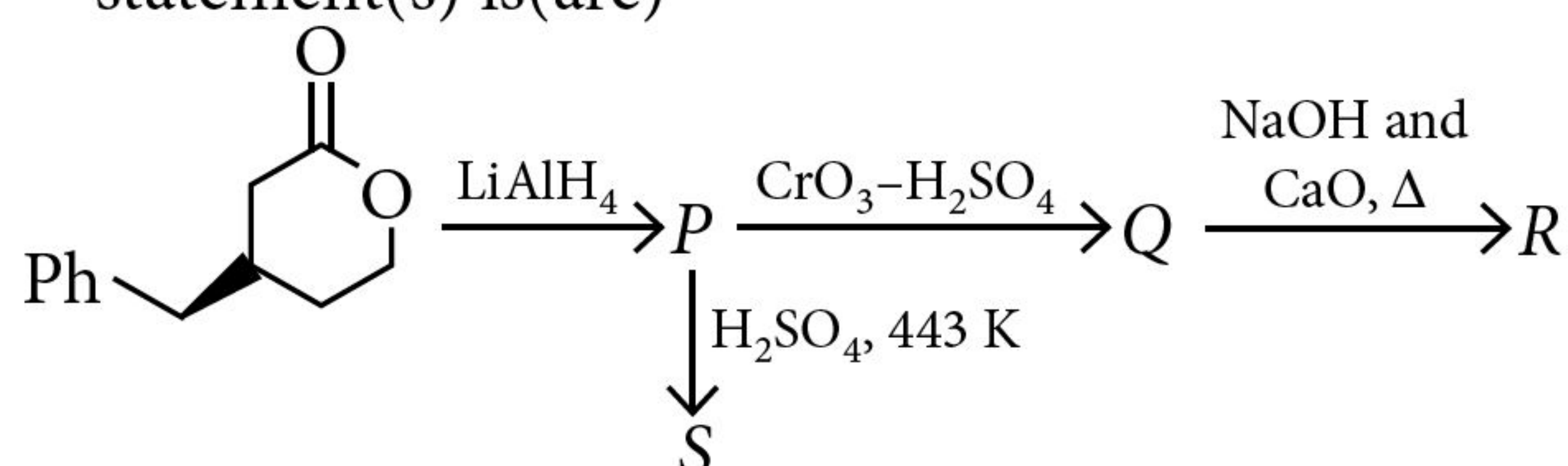
6. The compound(s) with P — H bond(s) is(are)

- (a) H_3PO_4 (b) H_3PO_3
(c) $\text{H}_4\text{P}_2\text{O}_7$ (d) H_3PO_2

7. For the reaction sequence given below, the correct statement(s) is(are)



- (a) Both X and Y are oxygen containing compounds.
- (b) Y on heating with CHCl_3/KOH forms isocyanide.
- (c) Z reacts with Hinsberg's reagent.
- (d) Z is an aromatic primary amine.
8. For the reaction sequence given below, the correct statement(s) is(are)



- (a) P is optically active (b) S gives Bayer's test
(c) Q gives effervescence with aq. NaHCO_3
(d) R is an alkyne.

SECTION 3 (MAXIMUM MARKS : 32)

- This section contains EIGHT (08) questions.
- The answer to each question is a NUMERICAL VALUE.
- For each question, enter the correct numerical value of the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.
- Answer to each question will be evaluated according to the following marking scheme:
Full Marks : +4 If ONLY the correct numerical value is entered in the designated place;
Zero Marks : 0 In all other cases.

9. The density (in g cm^{-3}) of the metal which forms a cubic close packed (ccp) lattice with an axial distance (edge length) equal to 400 pm is _____.
Use: Atomic mass of metal = 105.6 amu and Avogadro's constant = $6 \times 10^{23} \text{ mol}^{-1}$

10. The solubility of barium iodate in an aqueous solution prepared by mixing 200 mL of 0.010 M barium nitrate with 100 mL of 0.10 M sodium iodate is $X \times 10^{-6} \text{ mol dm}^{-3}$. The value of X is _____.
Use: Solubility product constant (K_{sp}) of barium iodate = 1.58×10^{-9}

11. Adsorption of phenol from its aqueous solution on to fly ash obeys Freundlich isotherm. At a given temperature, from 10 mg g^{-1} and 16 mg g^{-1} aqueous phenol solutions, the concentrations of adsorbed phenol are measured to be 4 mg g^{-1} and 10 mg g^{-1} , respectively. At this temperature, the concentration (in mg g^{-1}) of adsorbed phenol from 20 mg g^{-1} aqueous solution of phenol will be _____.
Use: $\log_{10} 2 = 0.3$

12. Consider a reaction $\text{A} + \text{R} \rightarrow \text{Product}$. The rate of this reaction is measured to be $k[\text{A}][\text{R}]$. At the start of the reaction, the concentration of R, $[\text{R}]_0$, is 10-times the concentration of A, $[\text{A}]_0$. The reaction can be considered to be a pseudo first order reaction with assumption that $k[\text{R}] = k'$ is constant. Due to this assumption, the relative error (in %) in the rate when this reaction is 40 % complete, is _____.
[k and k' represent corresponding rate constants]

13. At 300 K, an ideal dilute solution of a macromolecule exerts osmotic pressure that is expressed in terms of the height (h) of the solution (density = 1.00 g cm^{-3}) where h is equal to 2.00 cm. If the concentration of the dilute solution of the macromolecule is 2.00 g dm^{-3} , the molar mass of the macromolecule is calculated to be $X \times 10^4 \text{ g mol}^{-1}$. The value of X is _____.
Use: Universal gas constant (R) = $8.3 \text{ J K}^{-1} \text{ mol}^{-1}$ and acceleration due to gravity (g) = 10 m s^{-2}

14. An electrochemical cell is fueled by the combustion of butane at 1 bar and 298 K. Its cell potential is $\frac{X}{F} \times 10^3$ volts, where F is the Faraday constant. The value of X is _____.

Use: Standard Gibbs energies of formation at 298 K are: $\Delta_f G^\circ_{\text{CO}_2} = -394 \text{ kJ mol}^{-1}$; $\Delta_f G^\circ_{\text{water}} = -237 \text{ kJ mol}^{-1}$; $\Delta_f G^\circ_{\text{butane}} = -18 \text{ kJ mol}^{-1}$

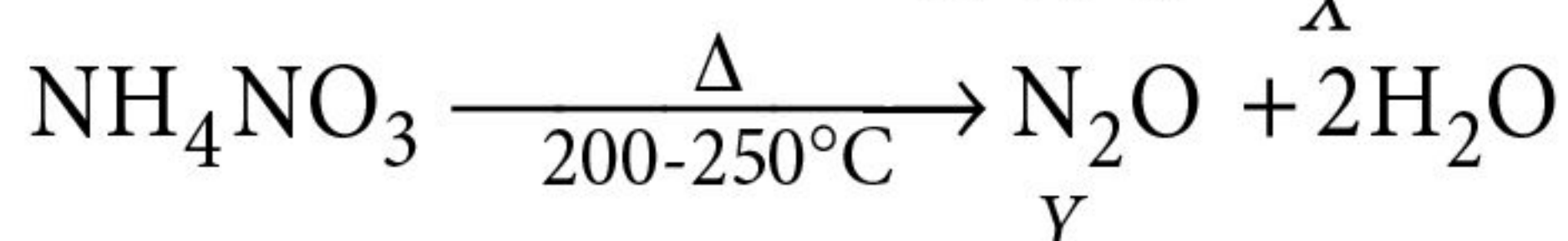
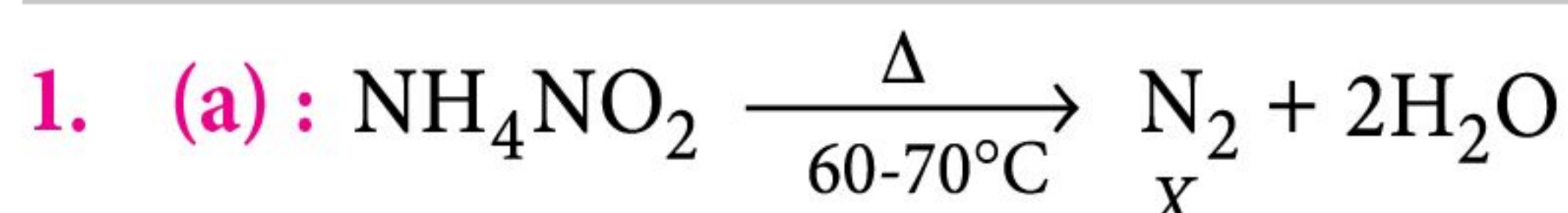
15. The sum of the spin only magnetic moment values (in B.M.) of $[\text{Mn}(\text{Br})_6]^{3-}$ and $[\text{Mn}(\text{CN})_6]^{3-}$ is ____.
16. A linear octasaccharide (molar mass = 1024 g mol^{-1}) on complete hydrolysis produces three monosaccharides: ribose, 2-deoxyribose and

glucose. The amount of 2-deoxyribose formed is 58.26 % (w/w) of the total amount of the monosaccharides produced in the hydrolyzed products. The number of ribose unit(s) present in one molecule of octasaccharide is ____.

Use: Molar mass (in g mol^{-1}): ribose = 150, 2-deoxyribose = 134, glucose = 180; Atomic mass (in amu): H = 1, O = 16

SOLUTIONS

PAPER-I



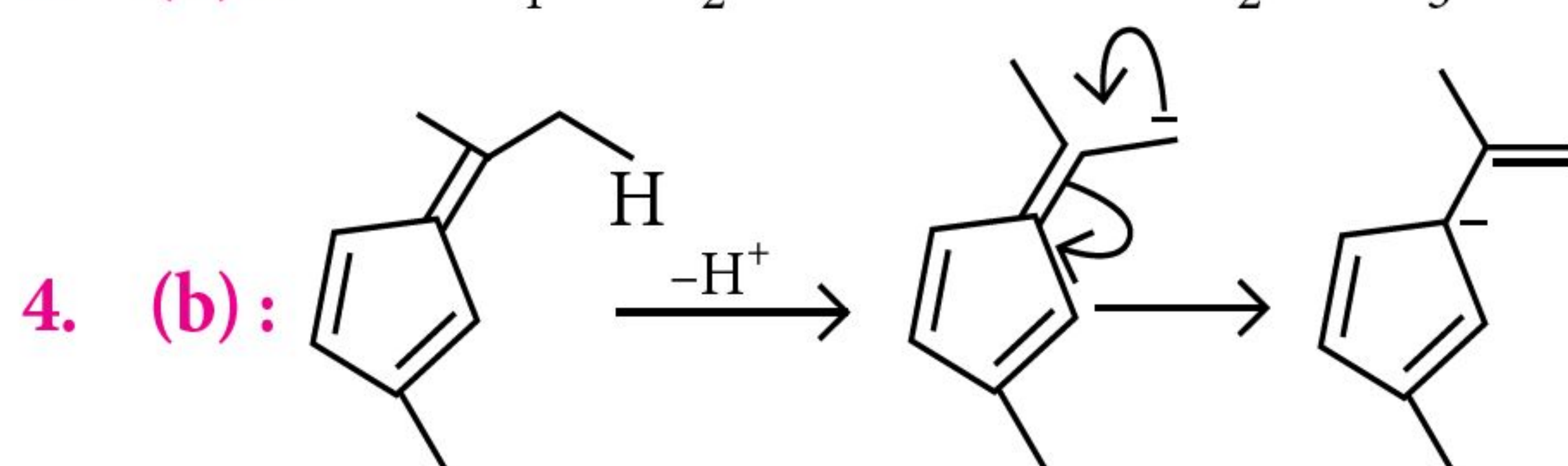
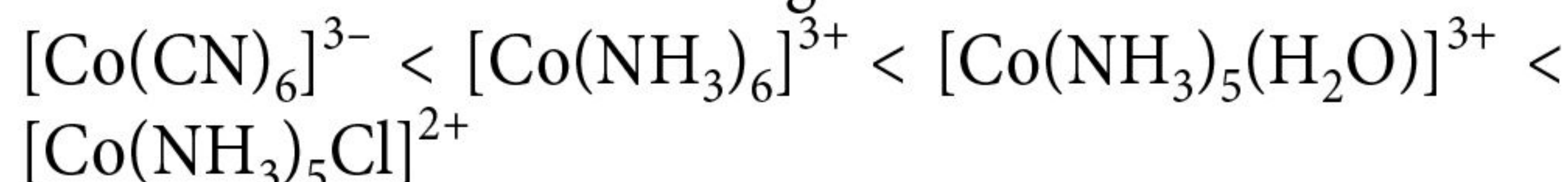
2. (a): As we know, energy $\propto$ ligand field strength

So, $\lambda_{\text{absorbed}} \propto \frac{1}{\text{ligand field strength}}$

Increasing order of ligand field strength is



So correct order of wavelength absorbed is



The carbanion thus formed is aromatic as well as resonance stabilised.

5. (b,c): Ne_2 : Bond order (B.O.) = $\frac{1}{2}[N_b - N_a]$
 $= \frac{1}{2}[10 - 10] = 0$

For F_2 , highest occupied molecular orbital (HOMO) is π^*2p .

Bond order of $\text{O}_2^+ = 2.5$

Bond order of $\text{O}_2 = 2.0$

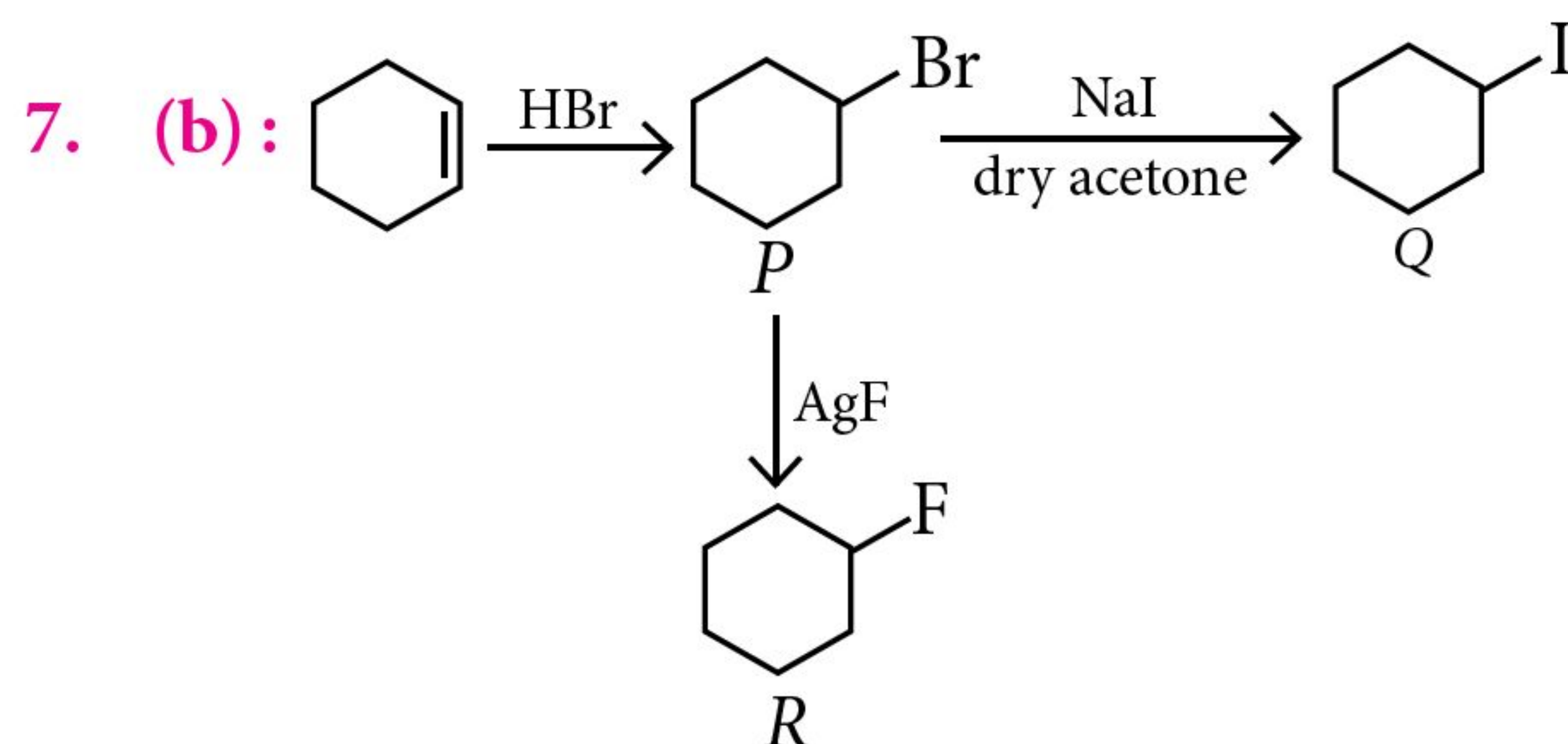
Bond order $\propto$ Bond energy $\propto \frac{1}{\text{Bond length}}$

So, O_2^+ has higher bond energy than O_2 .

Though Li_2 and B_2 both have same bond order i.e., 1, but larger atom forms larger bond.

So, bond length of Li_2 is larger than that of B_2 .

6. (a,b): Ions	Electronic configuration	Number of unpaired electron	Magnetic nature
$_{57}\text{La}^{3+}$	$[\text{Xe}]4f^05d^06s^0$	0	Diamagnetic
$_{58}\text{Ce}^{+4}$	$[\text{Xe}]4f^05d^06s^0$	0	Diamagnetic
$_{70}\text{Yb}^{2+}$	$[\text{Xe}]4f^{14}5d^06s^0$	0	Diamagnetic
$_{71}\text{Lu}^{3+}$	$[\text{Xe}]4f^{14}5d^06s^0$	0	Diamagnetic
$_{57}\text{La}^{2+}$	$[\text{Xe}]4f^05d^16s^0$	1	Paramagnetic
$_{58}\text{Ce}^{3+}$	$[\text{Xe}]4f^15d^06s^0$	1	Paramagnetic
$_{70}\text{Yb}^{3+}$	$[\text{Xe}]4f^{13}5d^06s^0$	1	Paramagnetic
$_{71}\text{Lu}^{2+}$	$[\text{Xe}]4f^{14}5d^16s^0$	1	Paramagnetic



Bond length order: $\text{C} - \text{I} > \text{C} - \text{Br} > \text{C} - \text{F}$
 (Q) (P) (R)

Bond enthalpy order: $\text{C} - \text{F} > \text{C} - \text{Br} > \text{C} - \text{I}$
 (R) (P) (Q)

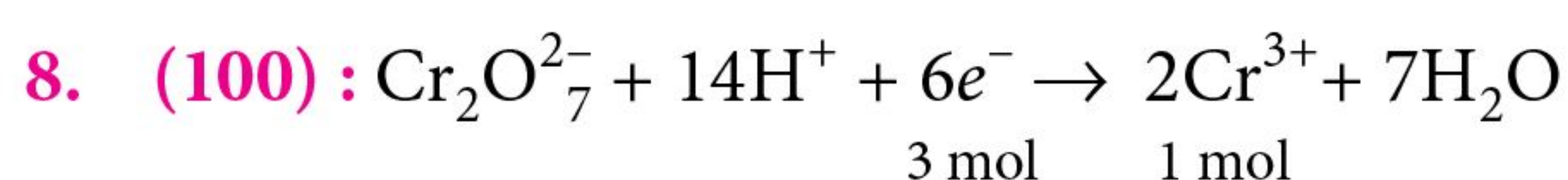
Rate of different halides towards $\text{S}_{\text{N}}2$ reaction:

$\text{C} - \text{I} > \text{C} - \text{Br} > \text{C} - \text{F}$
 (Q) (P) (R)

$K_a \propto \text{Acidic strength} \propto \frac{1}{\text{p}K_a}$

Acidic strength of conjugate acids: $\text{HI} > \text{HBr} > \text{HF}$

So, order of $\text{p}K_a$ value: $\text{HF} > \text{HBr} > \text{HI}$
 (R) (P) (Q)



$$Q = nF = 3 \times 96500 = 289500 \text{ C}$$

$$Q = It$$

$$289500 = I \times 48.25 \text{ min}$$

$$\Rightarrow I = \frac{289500}{48.25 \times 60}; I = 100 \text{ A}$$

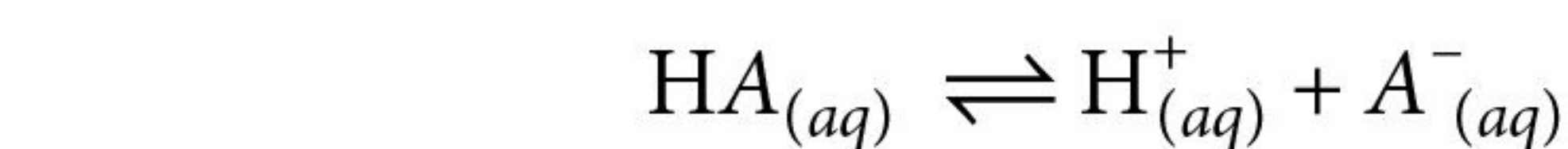
9. (2.23) : Given $[H^+] = X \times 10^{-7} \text{ M}$

$$K_a = 4 \times 10^{-11}$$

$$K_w = 1 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

Let the weak monobasic acid be HA.

The acid dissociates as :



$$\text{Initial conc.} \quad 10^{-3} \quad - \quad -$$

$$\text{After dissociation} \quad 10^{-3} - x \quad x \quad x$$

Water on dissociation gives H^+ and OH^- ions. Let the conc. of these ions be x' .

$$\text{Hence total } [H^+] = x + x'$$

$$[OH^-] = x'$$

$$\text{As, } [H^+][OH^-] = K_w$$

$$\text{So, } K_w = x' \times (x + x') = 1 \times 10^{-14} \quad \dots(i)$$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_a = \frac{(x + x')(x)}{10^{-3}} = 4 \times 10^{-11} \quad (10^{-3} - x \approx 10^{-3})$$

$$(x + x')(x) = 4 \times 10^{-14} \quad \dots(ii)$$

$$\text{Adding equation (i) and (ii), } (x + x')^2 = 5 \times 10^{-14}$$

$$x + x' = 2.23 \times 10^{-7} \text{ M}$$

So, the concentration of H^+ ions in aqueous solution of weak monobasic acid is $2.23 \times 10^{-7} \text{ M}$.

10. (-7.1) : According to van der Waals equation

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

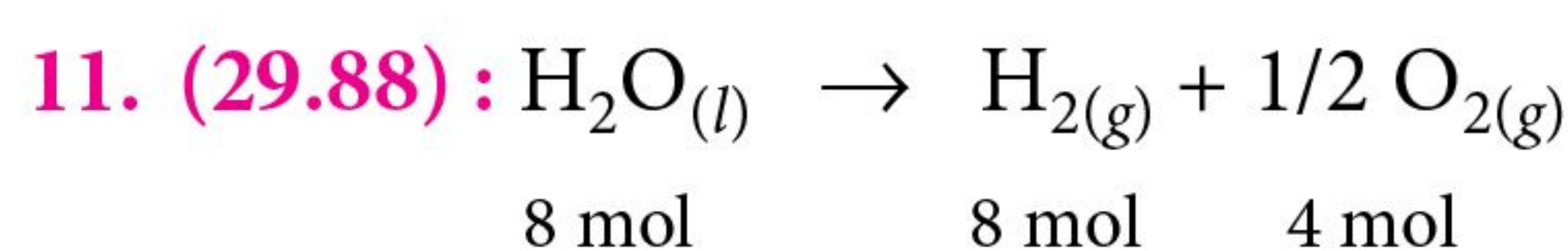
$$(PV_m^2 + a)(V_m - b) = V_m^2 RT$$

$$PV_m^3 + aV_m - ab - PV_m^2 b - V_m^2 RT = 0$$

$$PV_m^3 - (Pb + RT)V_m^2 + aV_m - ab = 0$$

So, ratio of coefficient of V_m^2 and V_m is

$$-\frac{(Pb + RT)}{a} = \frac{-(300 \times 0.060 + 0.082 \times 300)}{6.0} = -7.1$$



$$\text{Number of moles of water} = \frac{144}{18} = 8 \text{ mol}$$

$$w = -P\Delta V = -\Delta n_g RT$$

$$\Delta n_g = n_p - n_R = 12 - 0 = 12 \text{ mol}$$

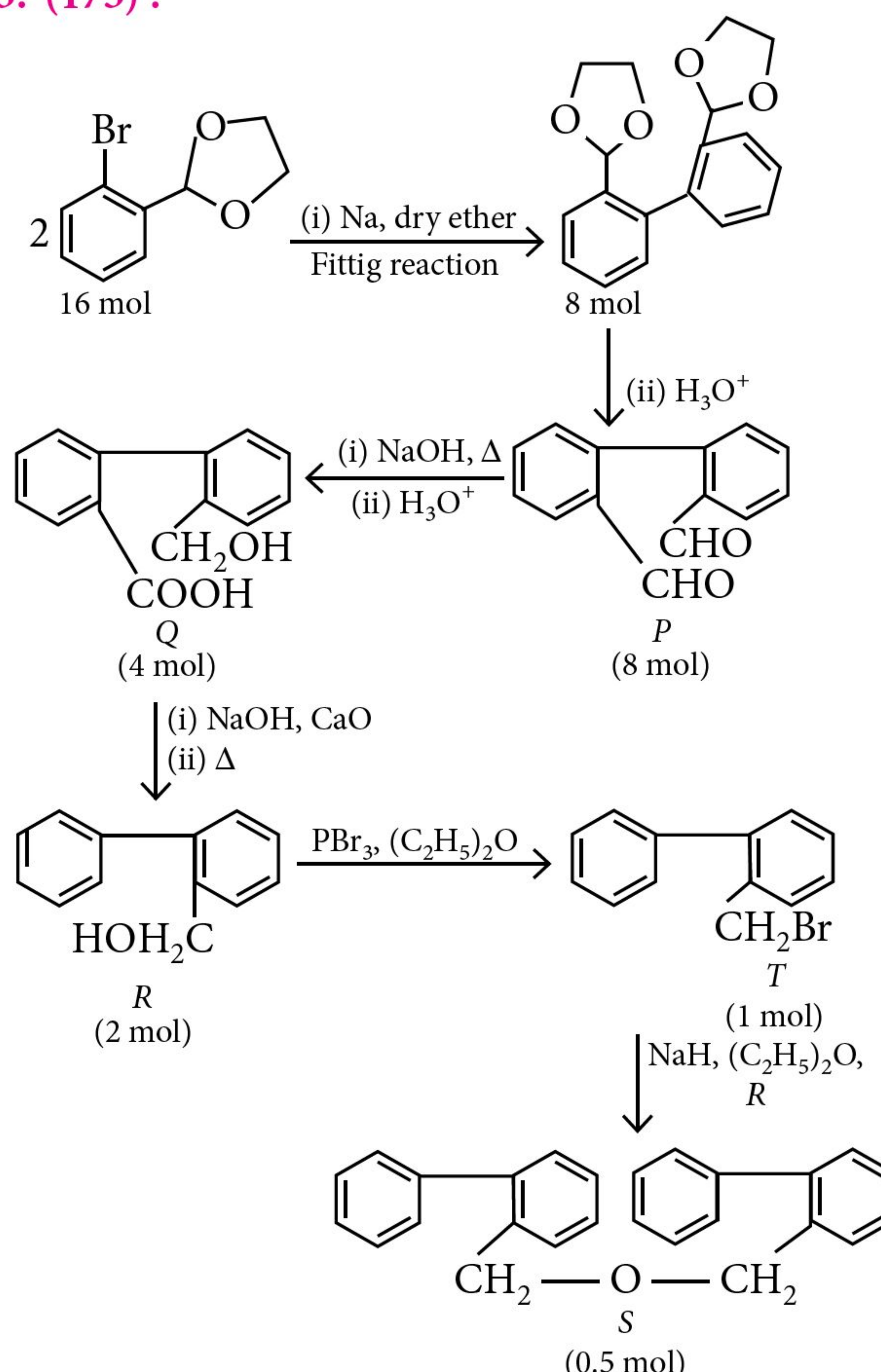
$$w = -12 \times 8.3 \times 300 = -29880 \text{ J} = -29.88 \text{ kJ}$$

12. (280) : The monomer of Nylon 6, 6 which gives positive carbylamine test is $NH_2 - (CH_2)_6 - NH_2$

10 mol of $NH_2 - (CH_2)_6 - NH_2$ gives 10 mol of nitrogen gas.

So, the amount of nitrogen gas evolved is $28 \times 10 = 280 \text{ g}$.

13. (175) :

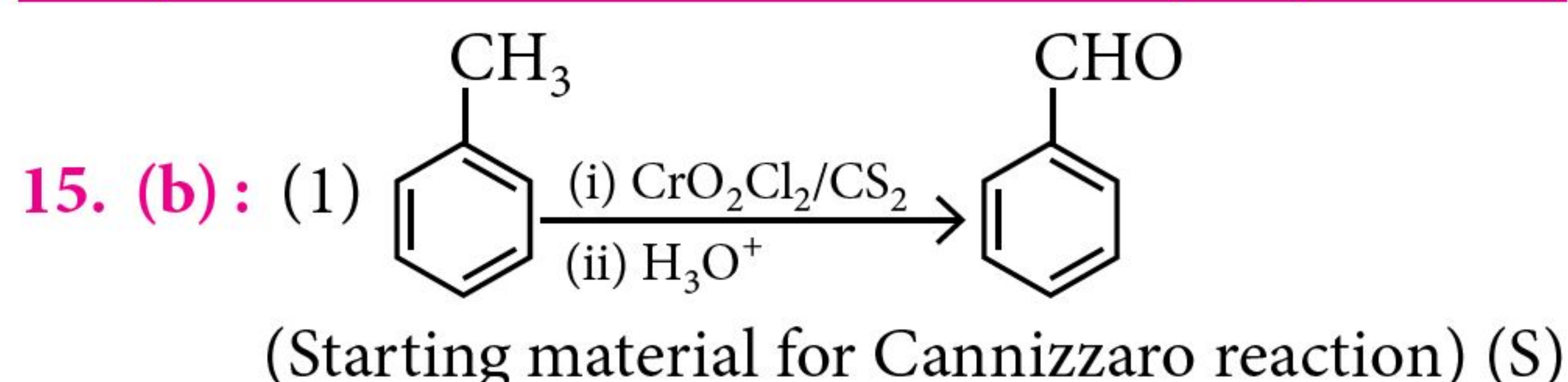


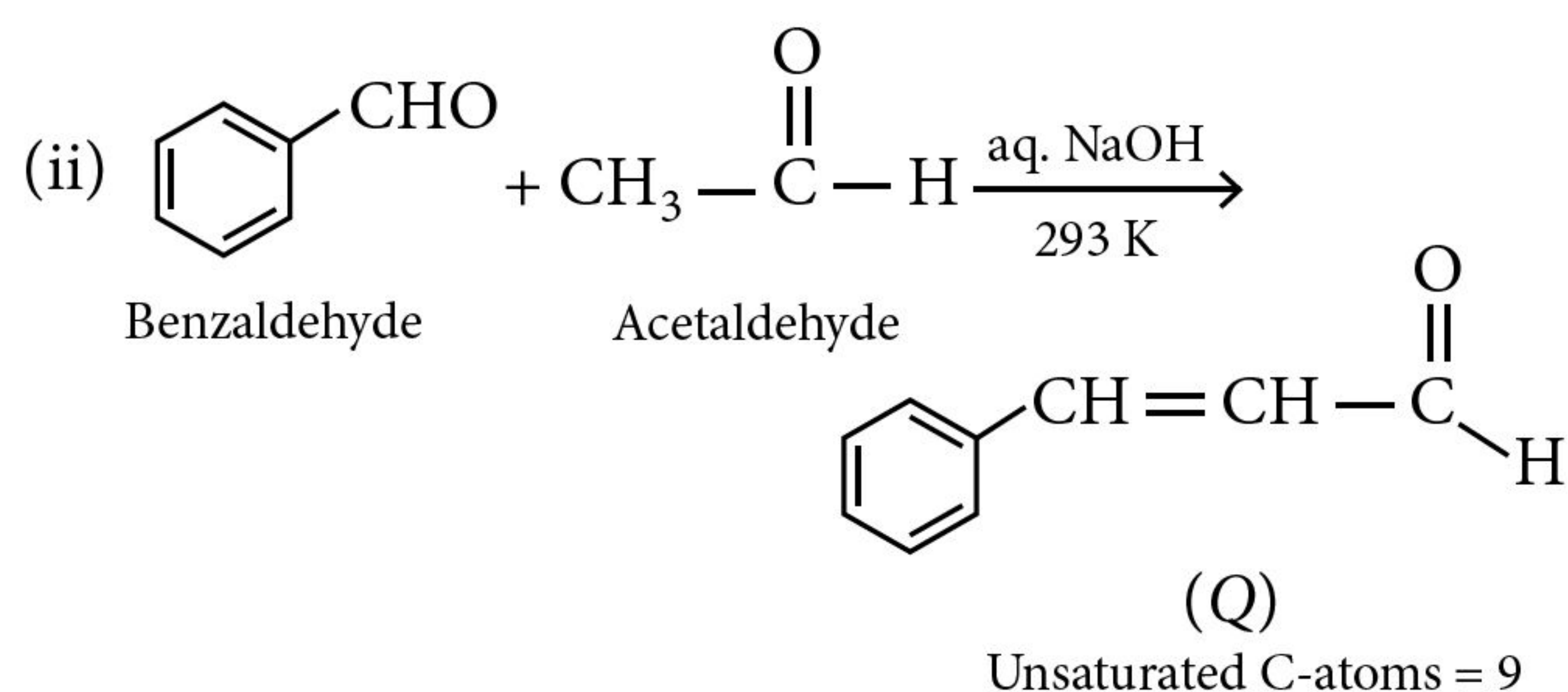
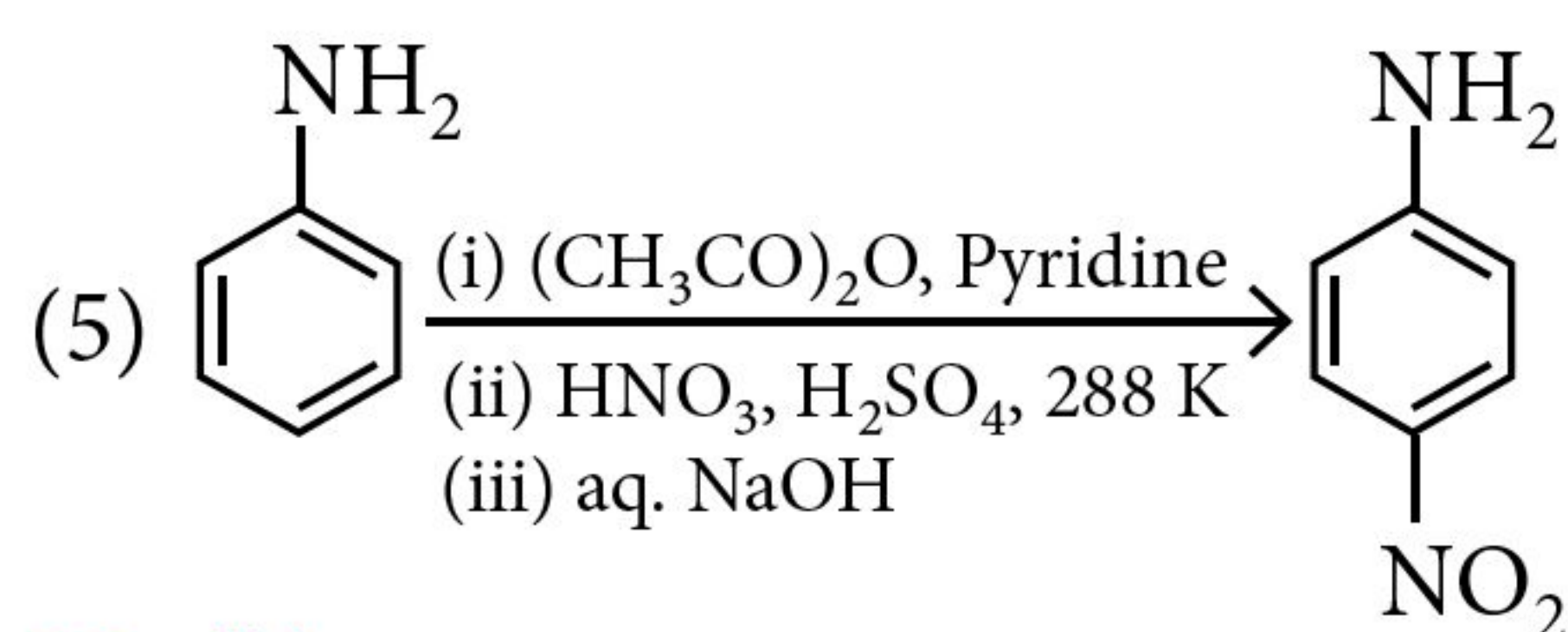
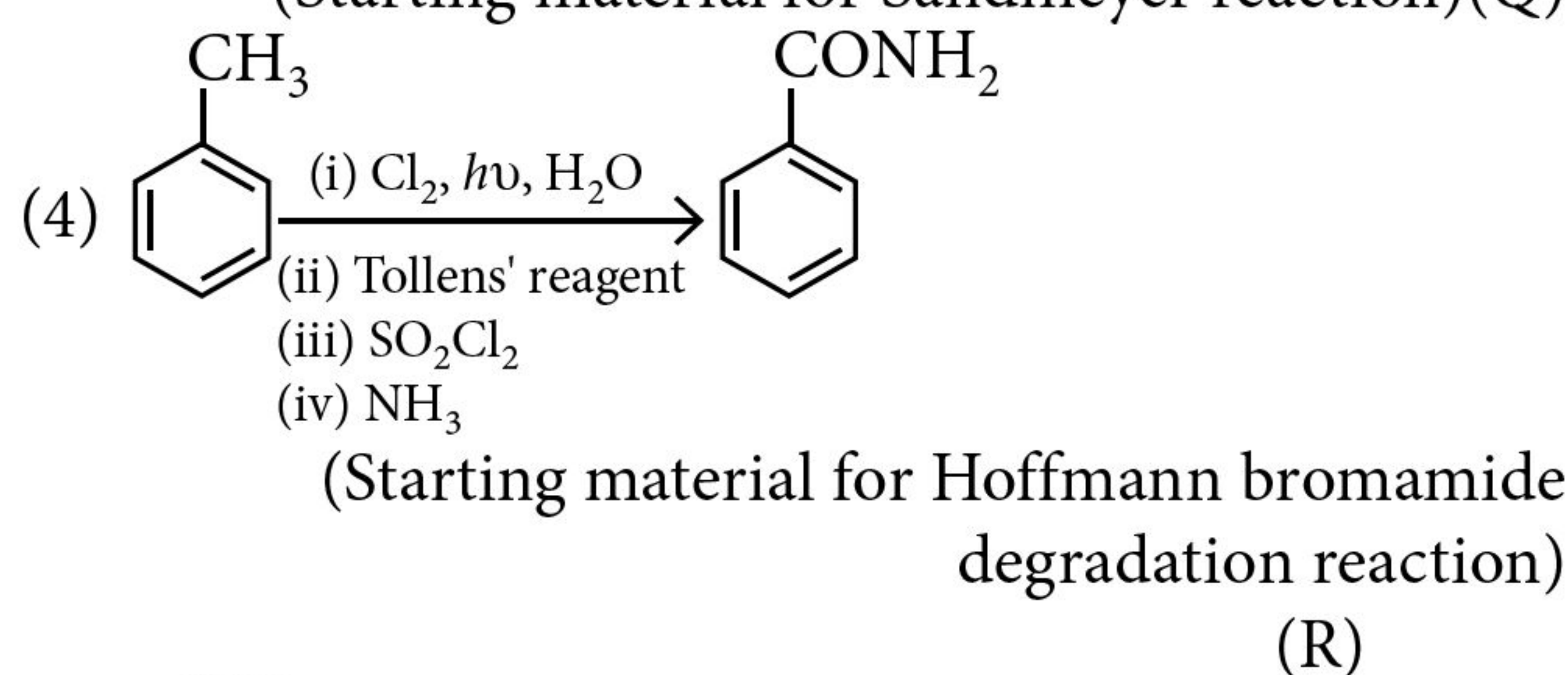
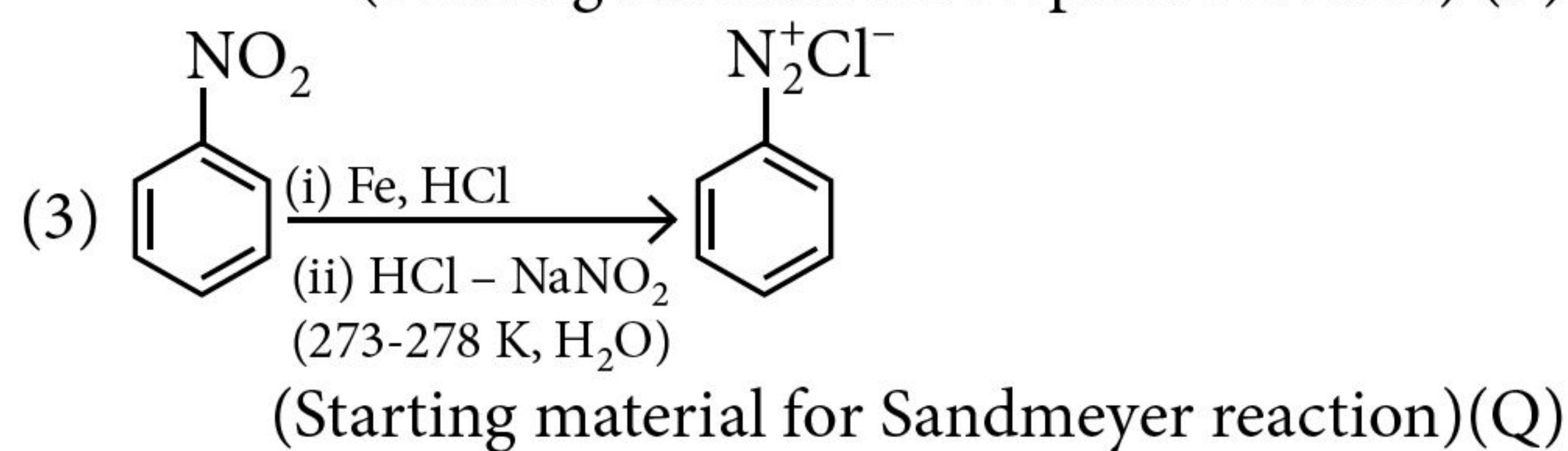
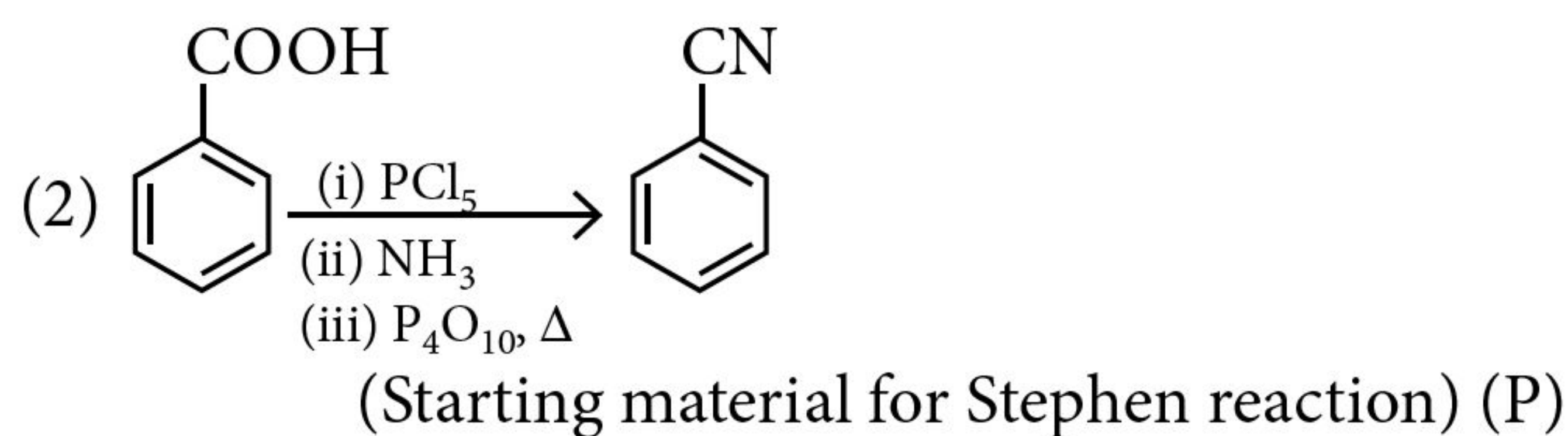
Molar mass of compound (S) = 350 g mol^{-1}

Amount of S produced is $0.5 \times 350 = 175 \text{ g}$

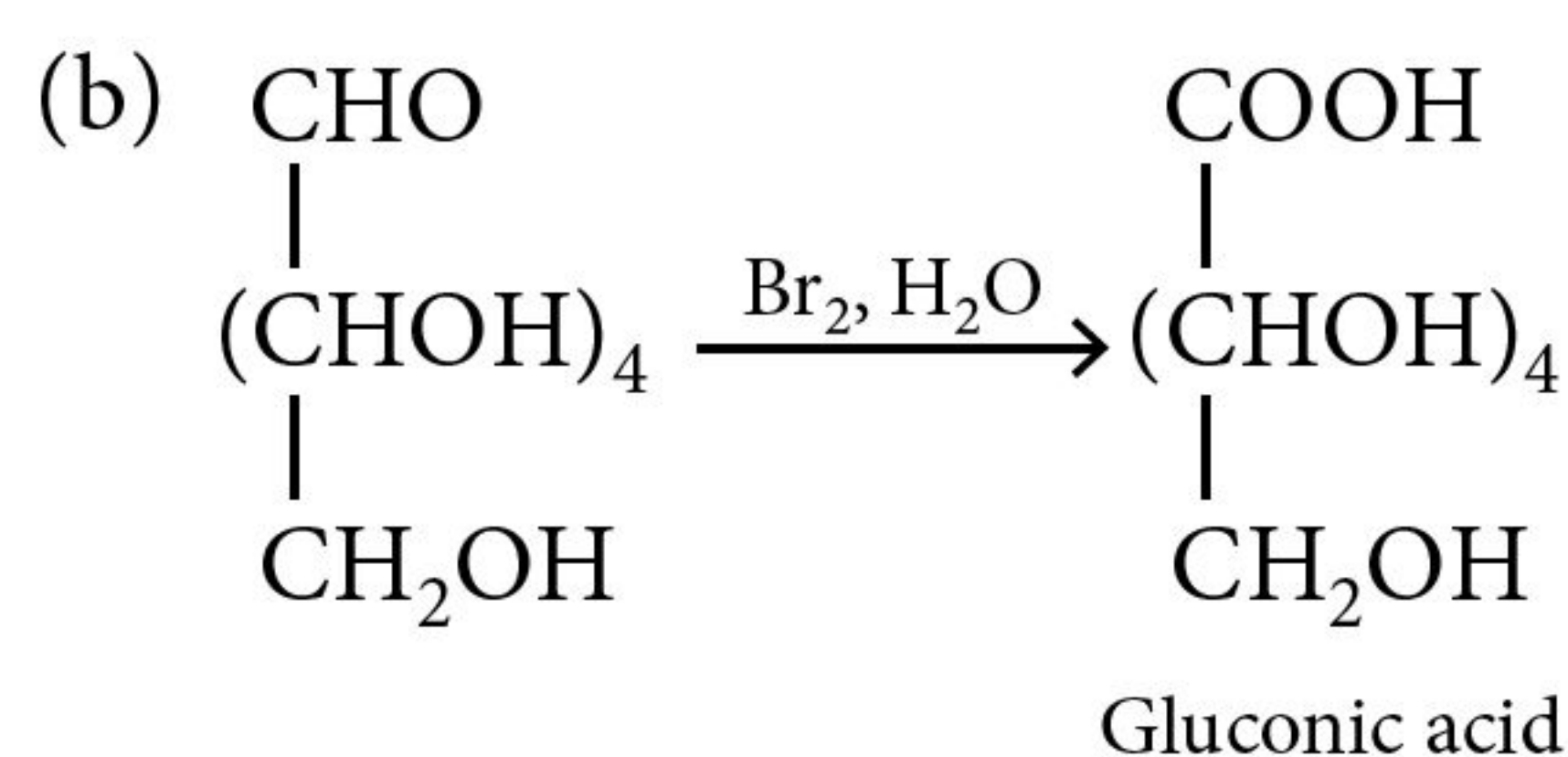
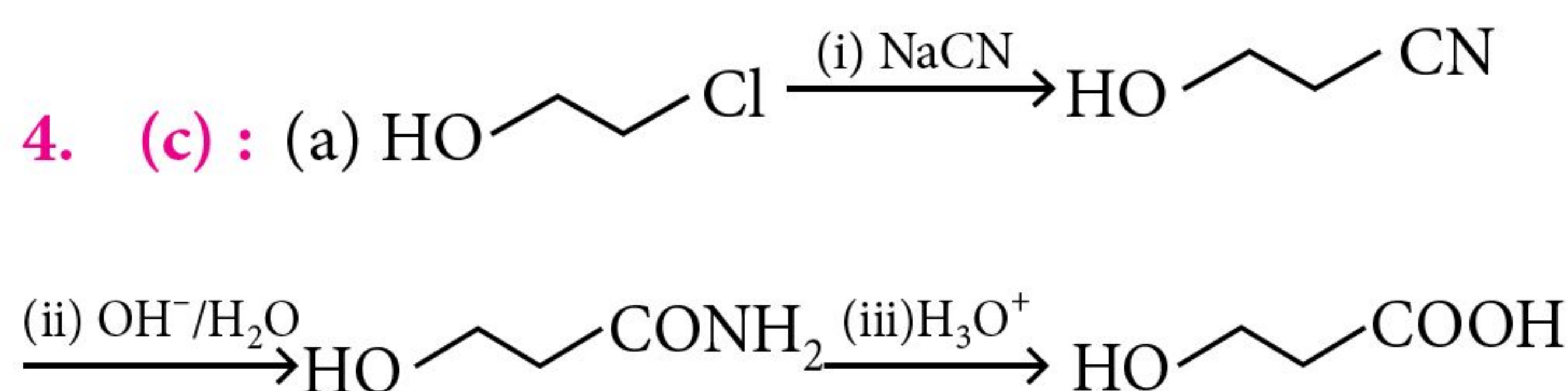
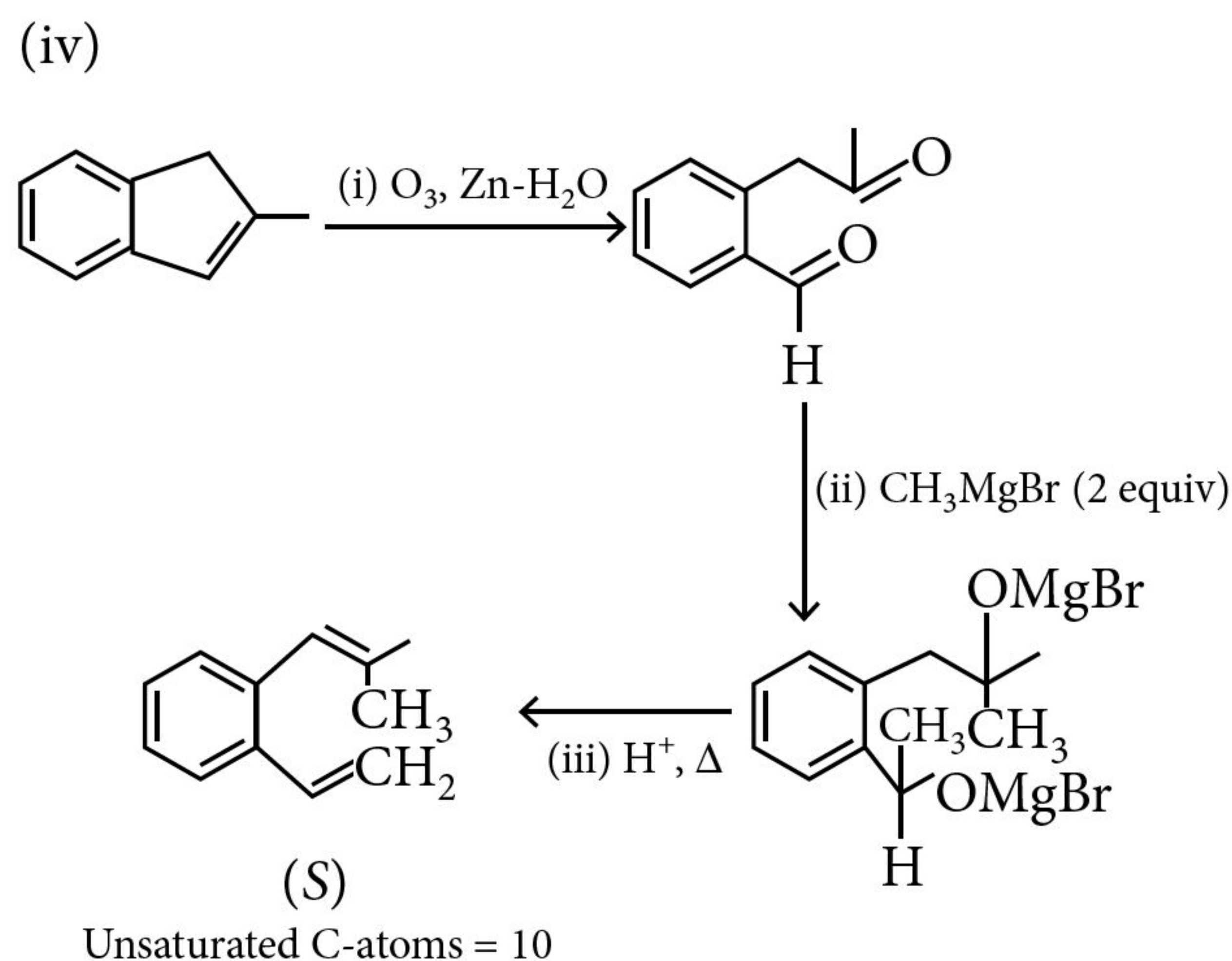
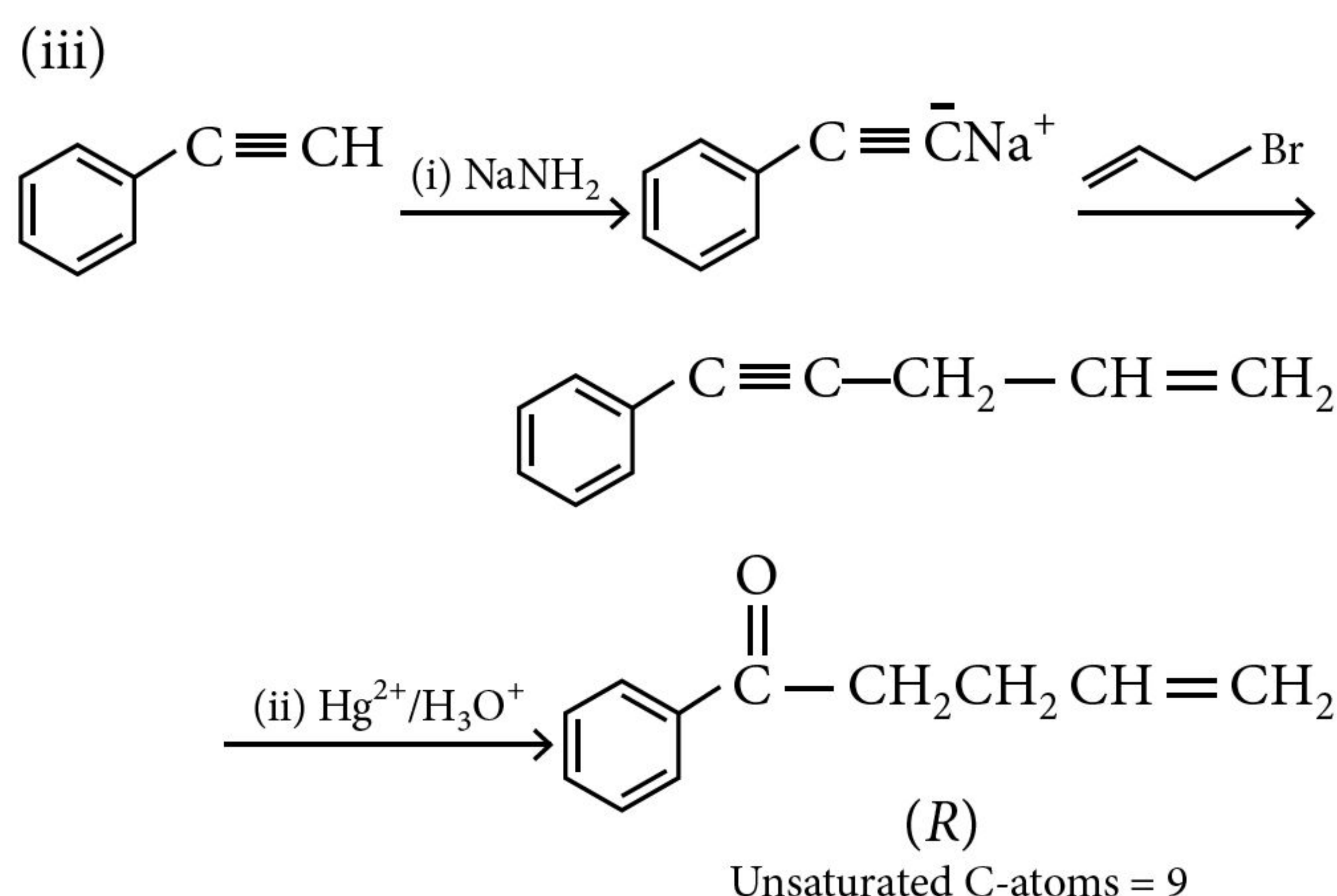
14. (a) :

List-I		List-II	
(P)	Passing H_2S in the presence of NH_4OH	3.	Mn^{2+}
(Q)	$(NH_4)_2CO_3$ in the presence of NH_4OH	4.	Ba^{2+}
(R)	NH_4OH in the presence of NH_4Cl	2.	Al^{3+}
(S)	Passing H_2S in the presence of dilute HCl	1.	Cu^{2+}





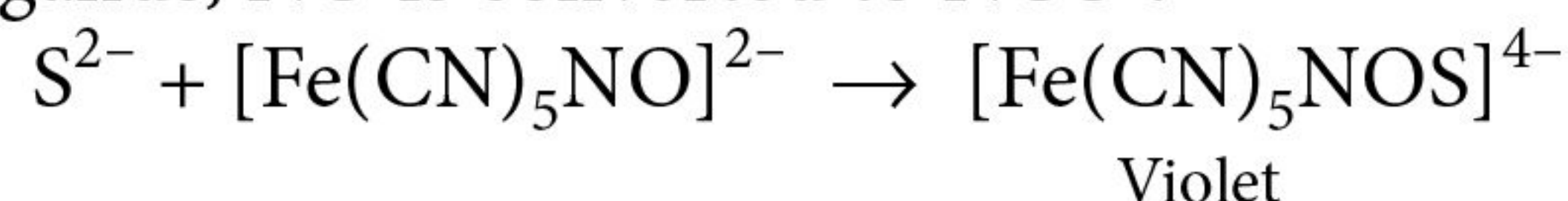
(Cross Aldol condensation reaction)



16. (b)

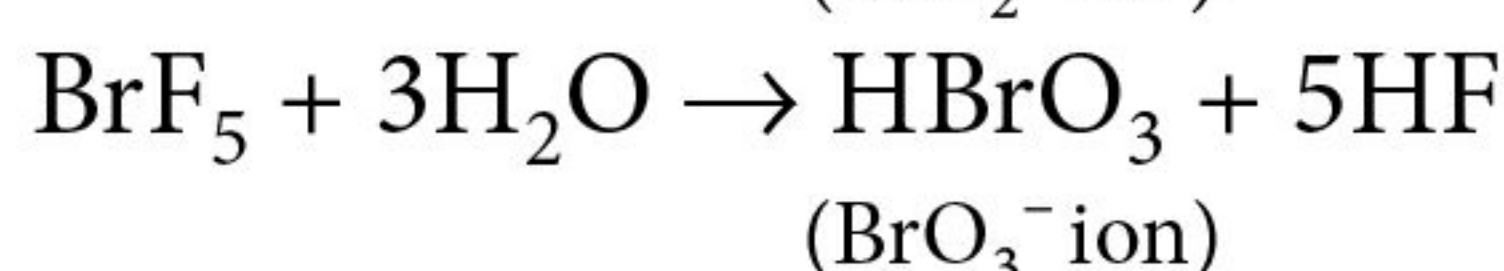
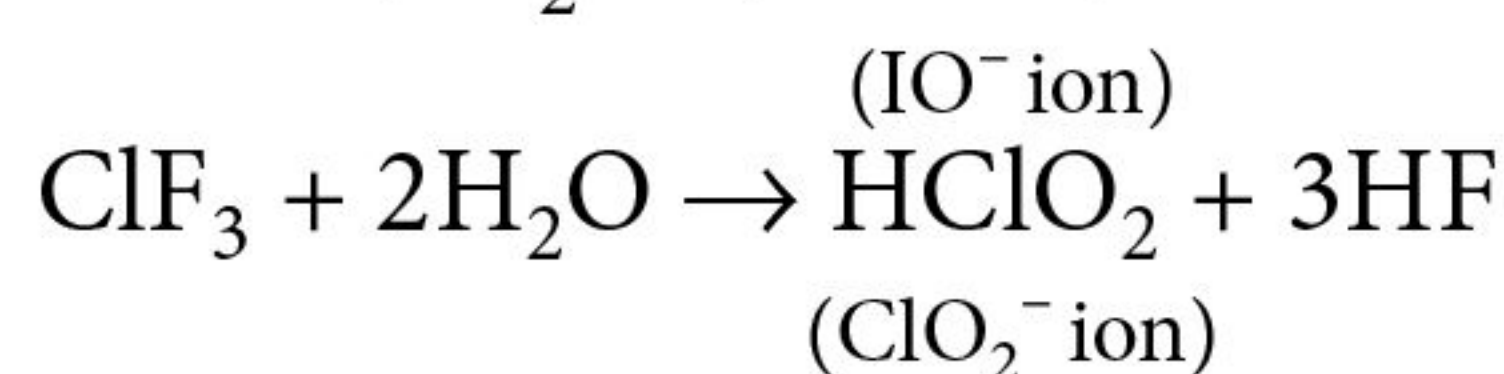
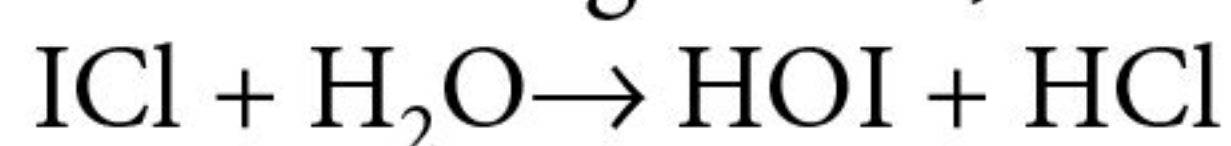
PAPER-II

1. (a) : $\text{Na}_2\text{S}(\text{S}^{2-}\text{ion})$ on reaction with sodium nitroprusside gives violet colouration in which one of the ligands, NO is converted to NOS^- .

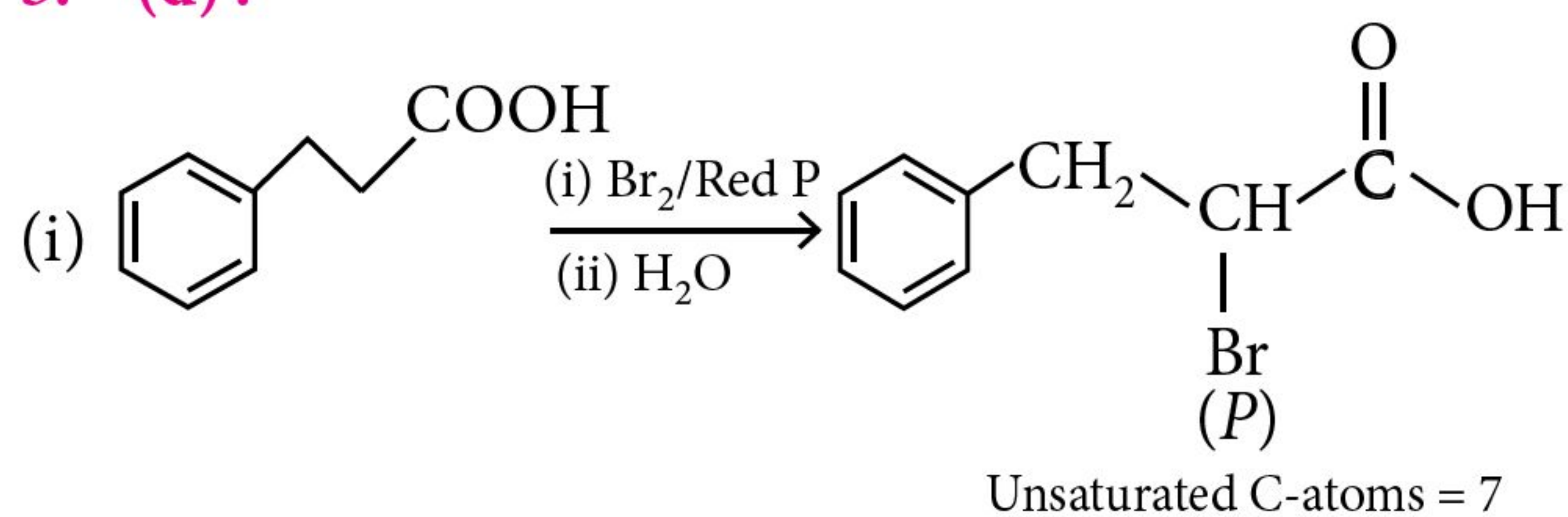


2. (a) : When interhalogen compounds undergo hydrolysis then halide ion (X^-) is derived from the smaller halogen and a hypohalide (with XX'), halite (with XX'_3) and halate (with XX'_5), anions are derived from the larger halogen.

Thus, the reactions can be given as,



3. (d) :



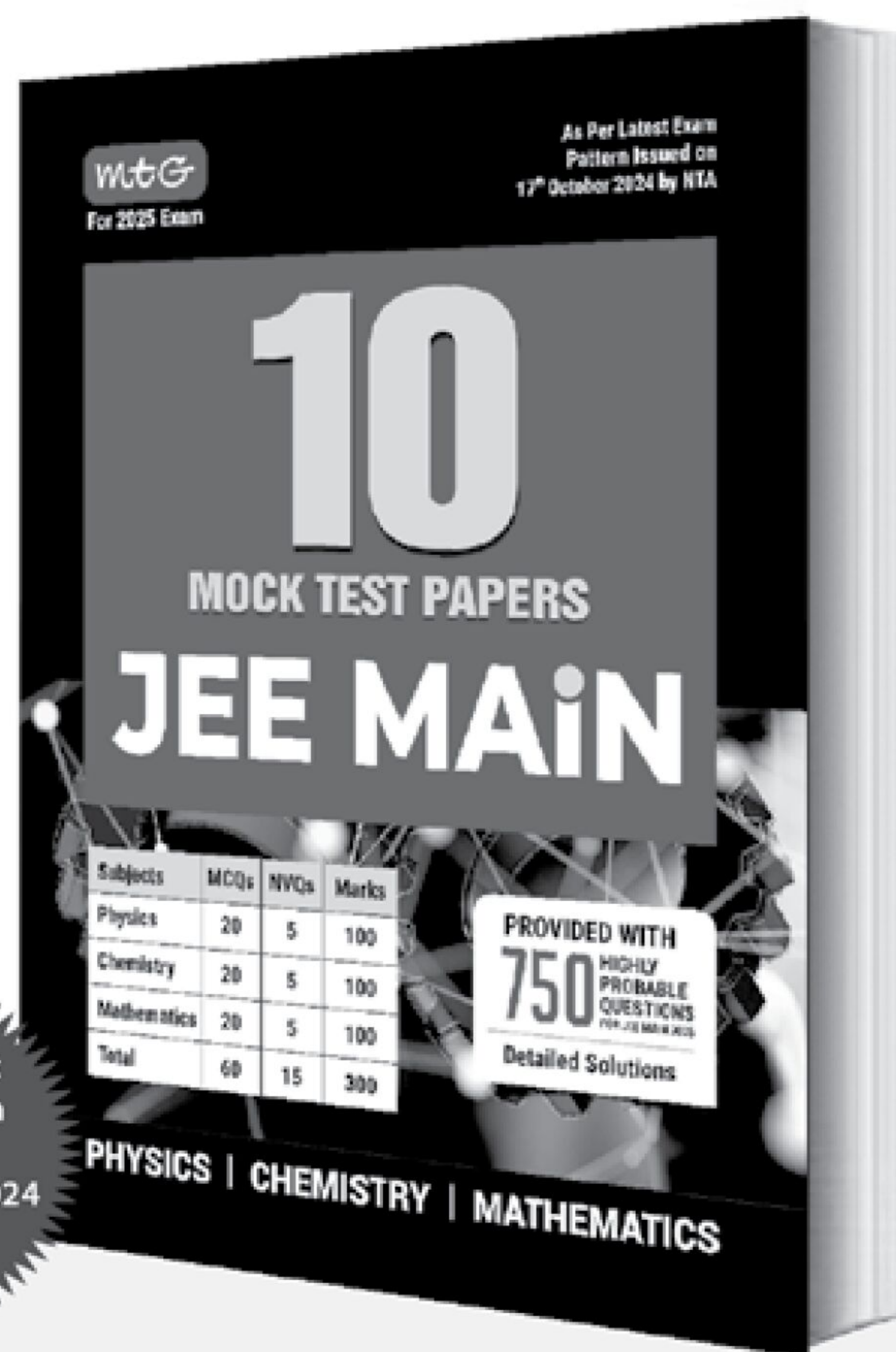
(Hell-Volhard-Zelinsky reaction)

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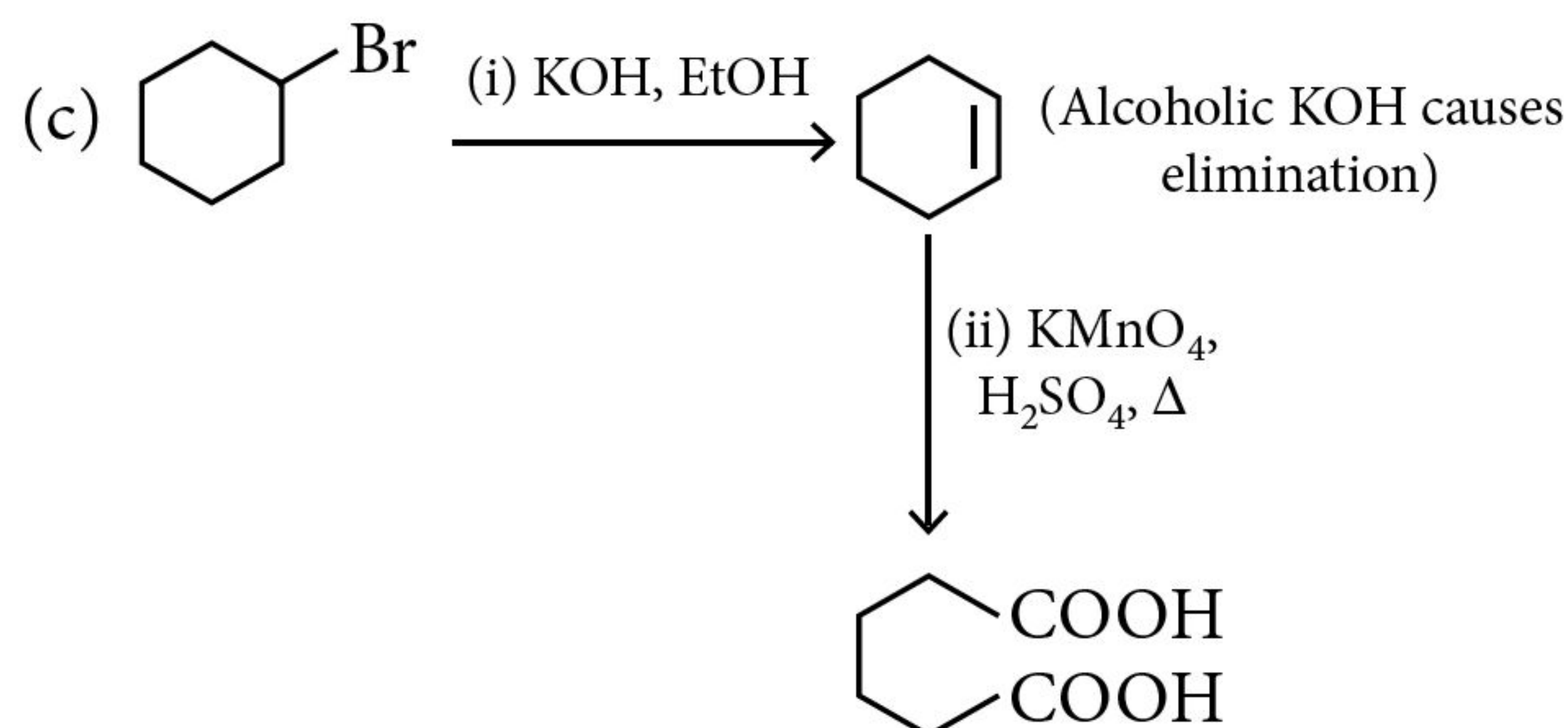
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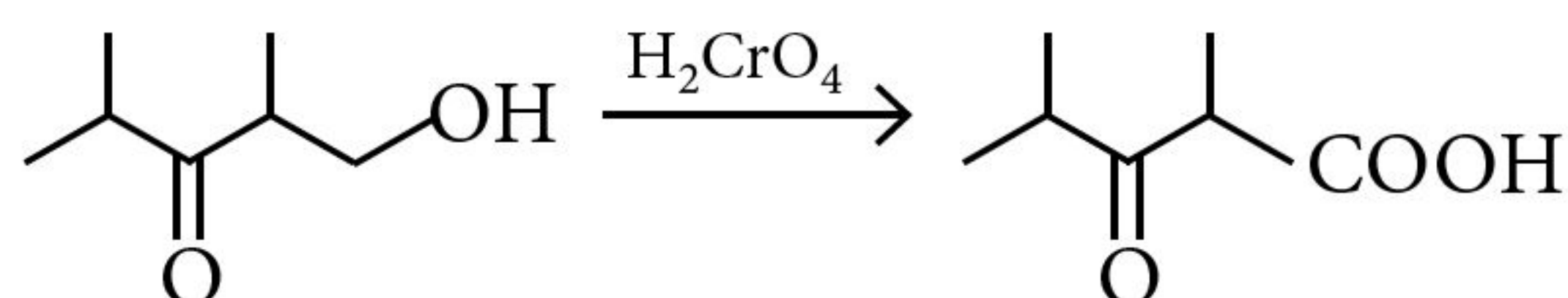
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(d) H_2CrO_4 is an oxidising agent which oxidises primary alcohols and aldehyde to carboxylic acids while oxidises secondary alcohols to ketones.

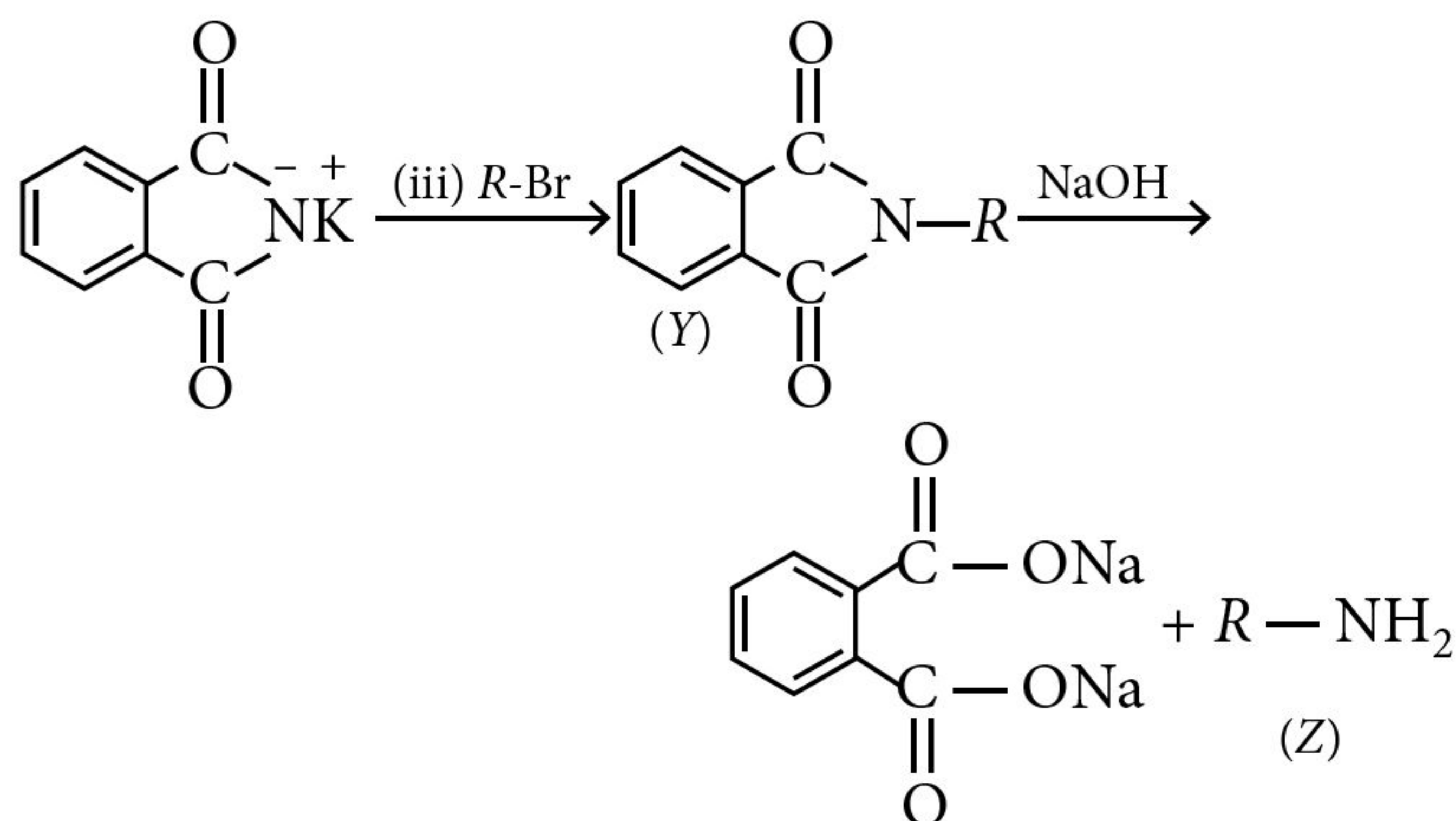
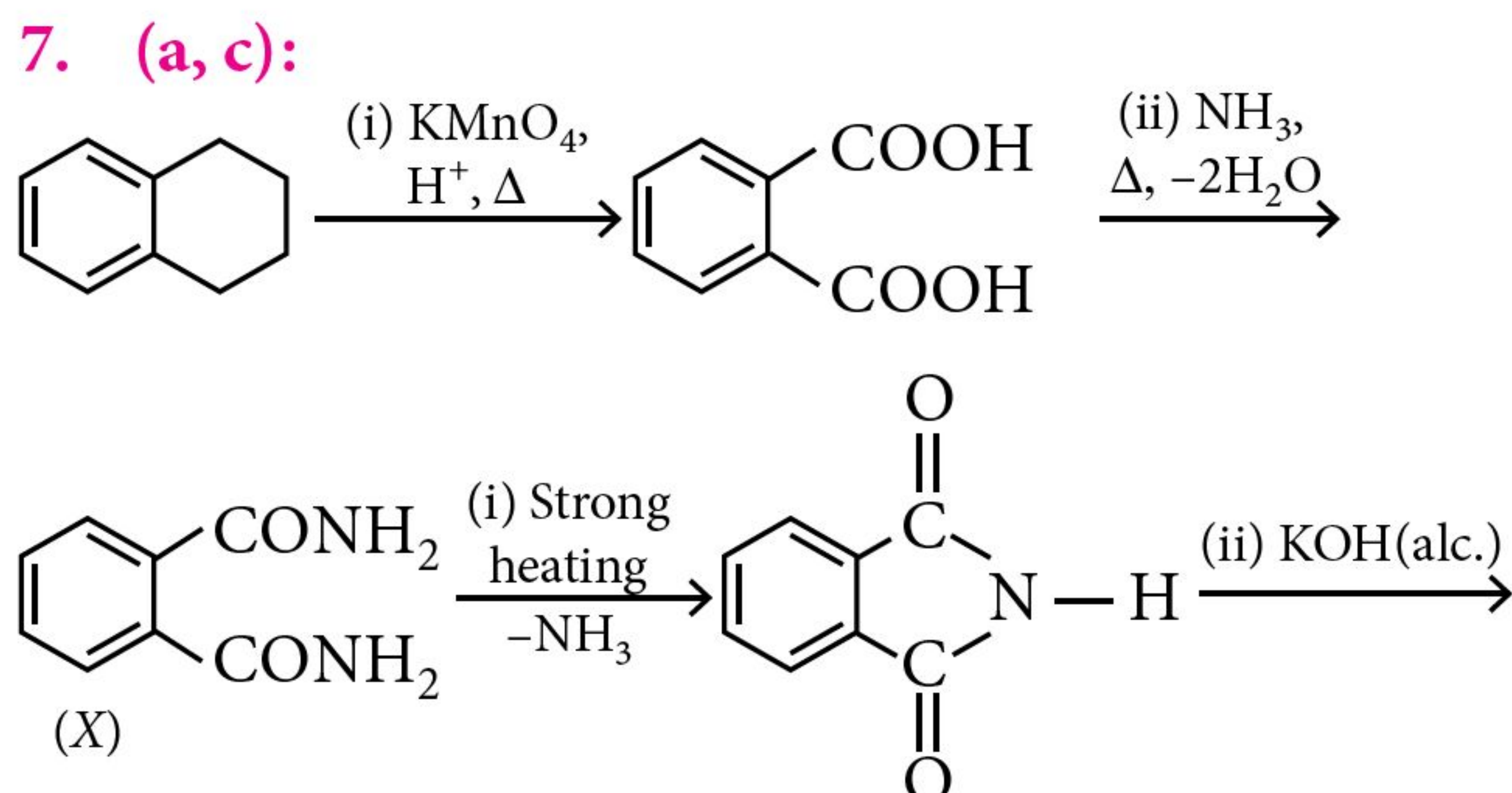
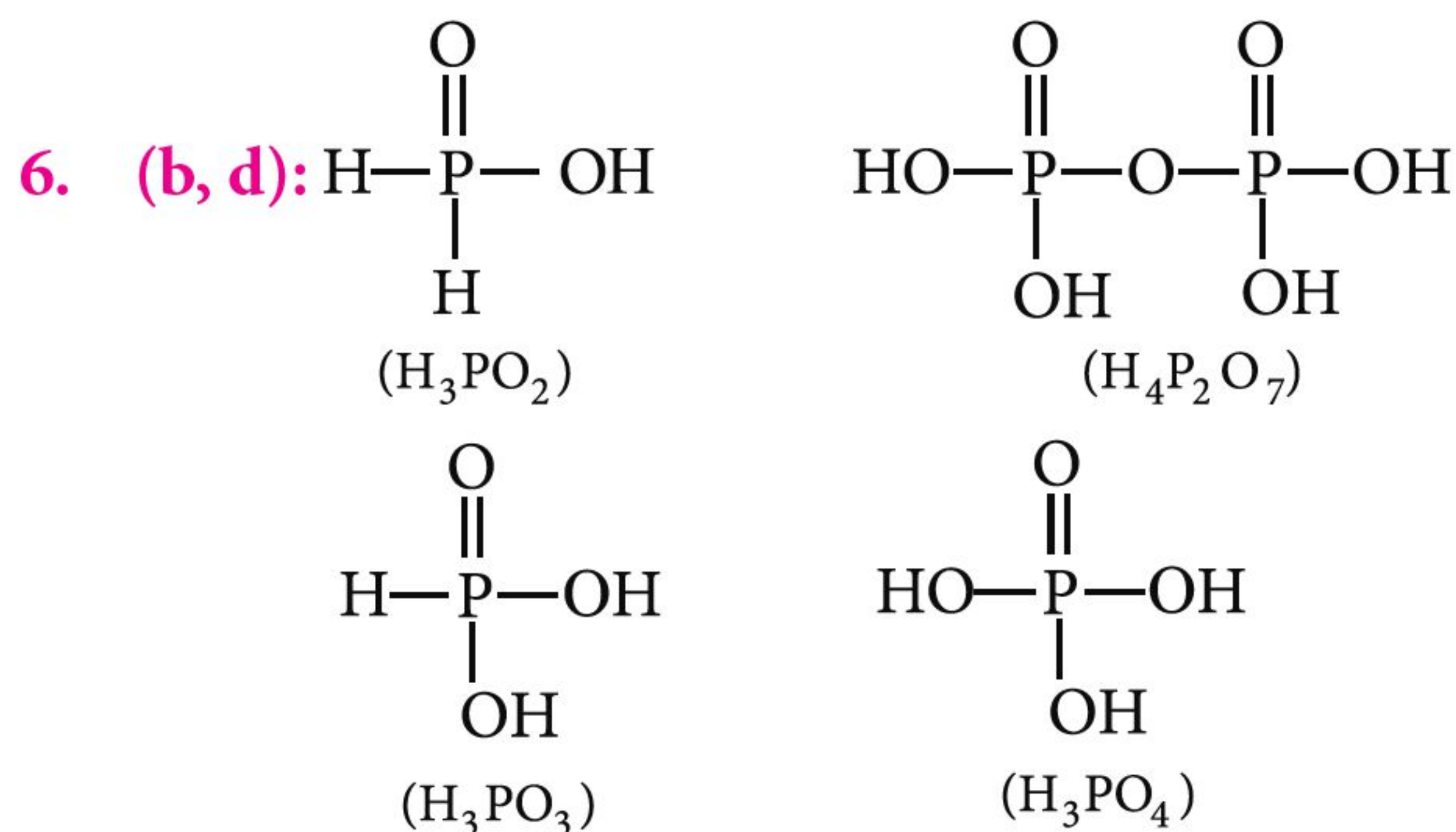


5. (c,d): Potential energy between two point charges varies as $1/r$ and between point charge and dipole varies as $1/r^2$. So, $1/r$ approaches to zero slowly as compared to $1/r^2$. Hence, statement (a) is incorrect.

In stationary polar molecules dipole-dipole interaction energy between the molecules is proportional to $1/r^3$ and that between the rotating polar molecules is proportional to $1/r^6$ where r is the distance between the polar molecules. Hence, statement (b) is incorrect.

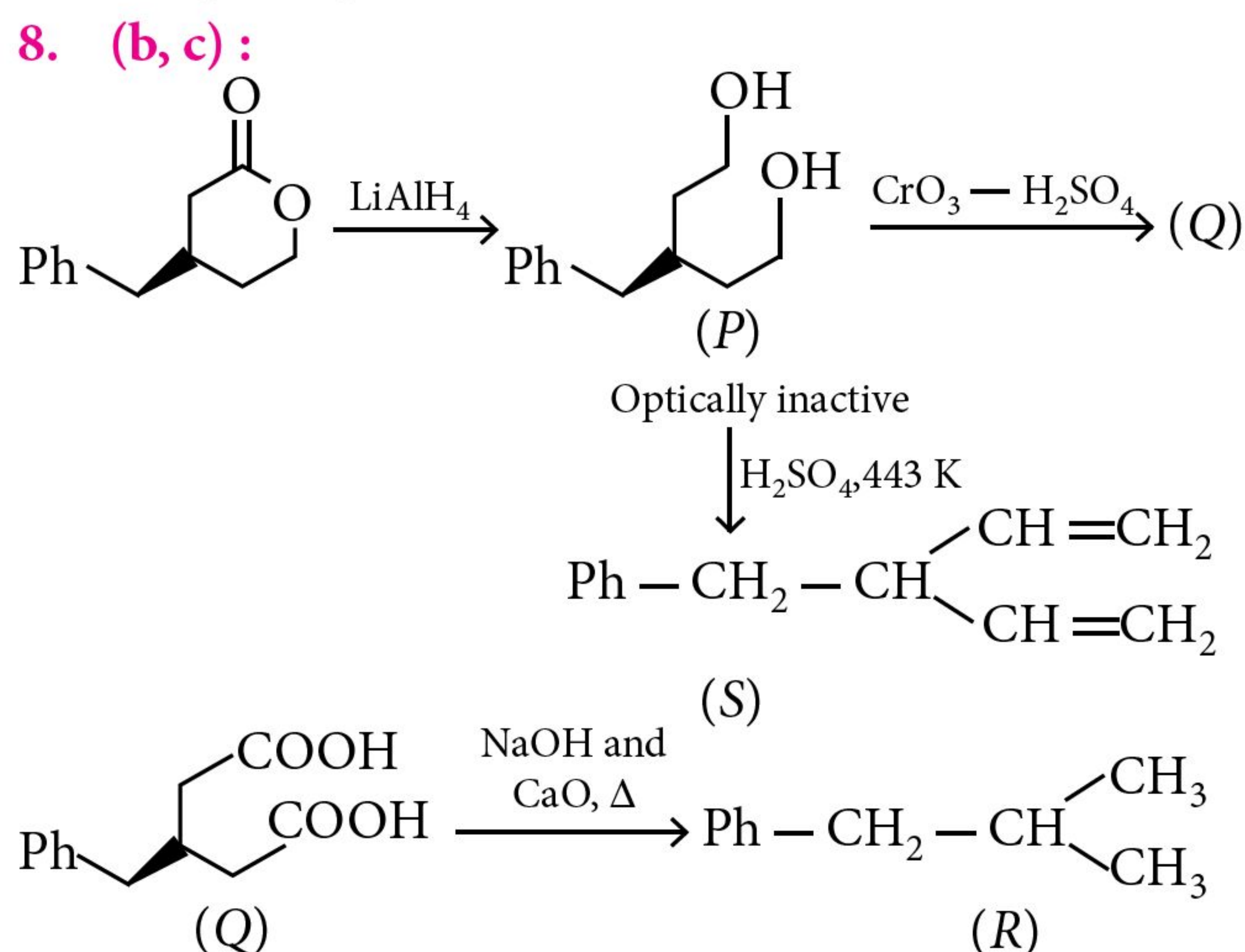
The dipole-induced dipole average interaction energy is independent of temperature. Hence, statement (c) is correct.

Non-polar molecules attract one another by London forces due to the production of instantaneous dipole or momentary dipole. Hence, statement (d) is correct.



X and Y both are oxygen containing compounds. Z (primary amine) on reaction with CHCl_3/KOH gives isocyanide, not Y.

Z is an aliphatic primary amine and it can react with Hinsberg's reagent.



P is optically inactive due to symmetry. S reacts with Baeyer's reagent (cold and dilute alkaline KMnO_4) due to the presence of unsaturation. Q gives effervescence of CO_2 with aq. NaHCO_3 . R is an alkane.

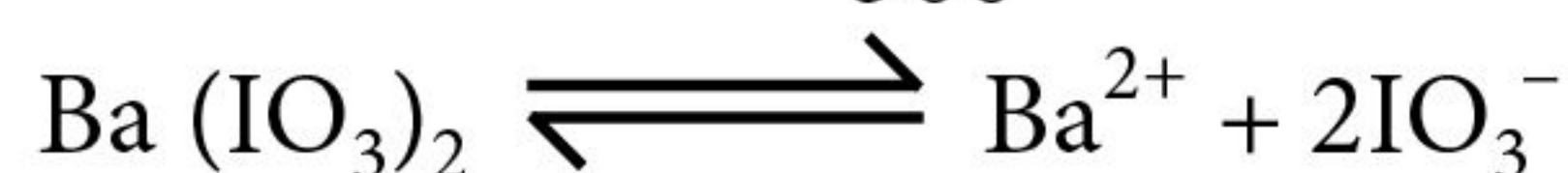
9. (11): Given, $a = 400 \text{ pm} = 400 \times 10^{-10} \text{ cm}$
 $M_A = 105.6 \text{ amu}$; $N_A = 6 \times 10^{23} \text{ mol}^{-1}$; $z = 4$ (for ccp)
 Density,

$$d = \frac{zM}{a^3 N_A} = \frac{4 \times 105.6}{(400 \times 10^{-10})^3 \times 6 \times 10^{23}} = 11 \text{ g cm}^{-3}$$

10. (3.95): $\text{Ba}(\text{NO}_3)_2 + 2\text{NaIO}_3 \rightarrow \text{Ba}(\text{IO}_3)_2 + 2\text{NaNO}_3$

Initial:	200 × 0.01	100 × 0.1		
mmol	= 2	= 10		
After reaction:	0	10 - 4 = 6mmol	2 mmol	4 mmol

$$\text{Conc. of } [\text{IO}_3^-] = \frac{6}{300} = 2 \times 10^{-2} \text{ mol dm}^{-3}$$



$$K_{sp} = [\text{Ba}^{2+}][\text{IO}_3^-]^2; 1.58 \times 10^{-9} = [\text{Ba}^{2+}](2 \times 10^{-2})^2$$

$$[\text{Ba}^{2+}] = \frac{1.58 \times 10^{-9}}{4 \times 10^{-4}} = 3.95 \times 10^{-6} \text{ mol dm}^{-3}$$

11. (15.62) : According to Freundlich adsorption

$$\text{isotherm } \frac{x}{m} = k(p)^{1/n}$$

In case of liquids it can be written as $\frac{x}{m} = k(C)^{1/n}$

Putting values :

$$4 = k(10)^{1/n} \quad \dots(i)$$

$$10 = k(16)^{1/n} \quad \dots(ii)$$

On dividing equation (ii) by (i)

$$\frac{10}{4} = \left(\frac{16}{10}\right)^{1/n}$$

On taking log, $\log 10 - \log 4 = \frac{1}{n}(\log 16 - \log 10)$

$$1 - 2 \log 2 = \frac{1}{n} (4 \log 2 - 1) \text{ or } 1 - 0.6 = \frac{1}{n} (1.2 - 1)$$

$$\frac{1}{n} = \frac{0.4}{0.2} = 2$$

For $C = 20$ mg/g, let conc. of adsorbed phenol be x .

$$\frac{x}{1} = k(20)^{1/n} \quad \dots(iii)$$

On dividing equation (iii) by (ii)

$$\frac{x}{10} = \left(\frac{20}{16}\right)^{1/n} ; \text{ as } \frac{1}{n} = 2$$

$$\text{Hence } \frac{x}{10} = \left(\frac{5}{4}\right)^2, x = 10 \times \left(\frac{5}{4}\right)^2 = 15.625 \text{ mg/g}$$

12. (4.17) : $A + R \rightarrow \text{Product}$

Initial conc.	A_0	$10A_0$
At 40% completion	$A_0 - 0.4A_0$ $= 0.6 A_0$	$10A_0 - 0.4A_0$ $= 9.6A_0$

$$\text{Rate} = k[A][R] = k[0.6A_0][9.6A_0] = 5.76 k[A_0]^2$$

If assumed that conc. of reactant in excess remains constant

$$k' = k[10A_0]$$

$$\text{Now rate } R' = k'[A] = k[10A_0](0.6A_0) = 6 kA_0^2$$

$$\text{Error} = 6 k[A_0]^2 - 5.76 kA_0^2 = 0.24 k[A_0]^2$$

$$\text{Relative error} = \frac{\text{Error}}{\text{True value}} \times 100\%$$

$$= \frac{0.24k[A_0]^2}{5.76k[A_0]^2} \times 100 = 4.17\%$$

13. (2.49) : Height (h) = 2 cm = 2×10^{-2} m

$$d = 1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$$

$$g = 10 \text{ m s}^{-2}$$

$$\text{Osmotic pressure } (\pi) = hdg = 2 \times 10^{-2} \times 1000 \times 10 = 200 \text{ N m}^{-2}$$

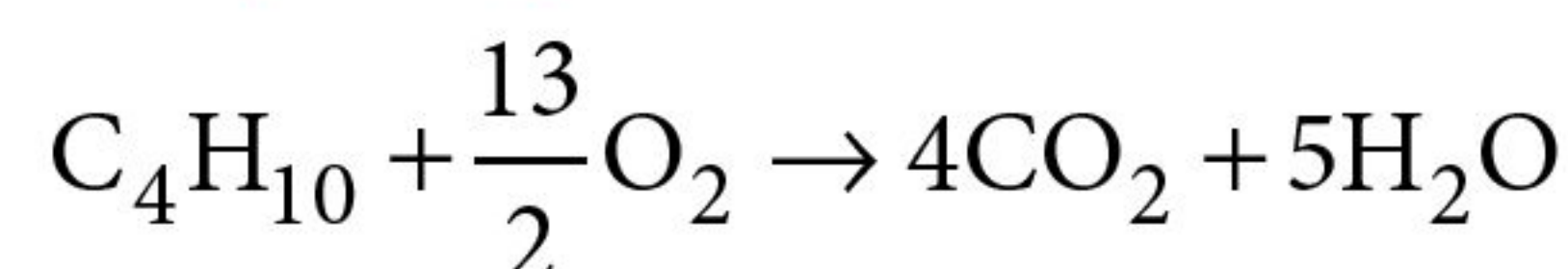
Osmotic pressure can also be given as $\pi = CRT$

$$C = \frac{2.00}{\text{Molar mass}} \text{ mol/L} = \frac{2000}{\text{Molar mass}} \text{ mol/m}^3$$

$$200 = \frac{2000}{\text{Molar mass}} \times 8.3 \times 300$$

$$\text{Molar mass} = \frac{2000 \times 300 \times 8.3}{200} = 2.49 \times 10^4 \text{ g mol}^{-1}$$

14. (105.5) : Combustion of butane can be written as



$$\Delta G^\circ_{\text{reaction}} = 4 \times \Delta_f G^\circ_{\text{CO}_2} + 5(\Delta_f G^\circ_{\text{H}_2\text{O}}) - (\Delta_f G^\circ_{\text{butane}})$$

$$= 4 \times (-394) + 5(-237) - (-18) = -2743 \text{ kJ/mol}$$

$$\Delta G^\circ = -nFE^\circ$$

$$E^\circ = -\frac{\Delta G^\circ}{nF}$$

Change in oxidation state of each carbon atom from reactant (-2.5) to product (+4) is 6.5.

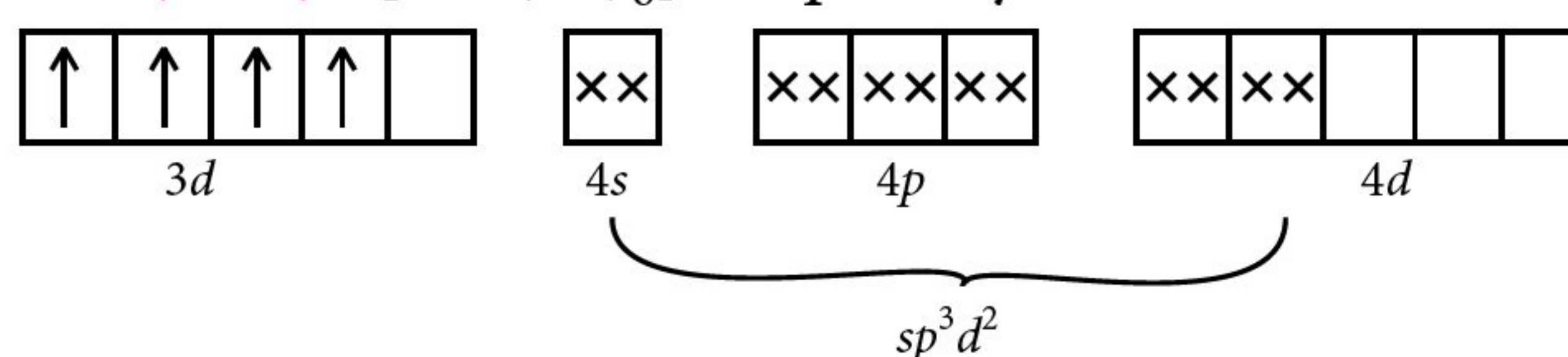
Thus, for 4 carbon atoms, change in oxidation state = $6.5 \times 4 = 26$

Electron involved (n) = 26

$$E^\circ = -\left(\frac{-2743 \times 10^3}{26 \times F}\right) \text{ Volts} = \frac{105.5 \times 10^3}{F} \text{ Volts}$$

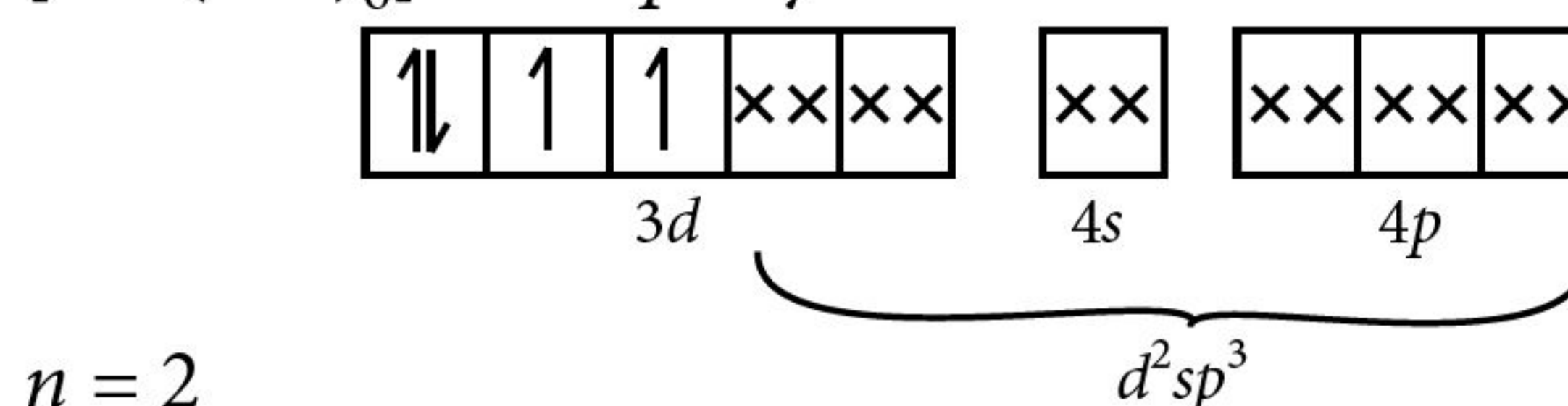
Hence $X = 105.5$

15. (7.73) : $[\text{Mn}(\text{Br})_6]^{3-}$: sp^3d^2 hybridised



$$n = 4, \mu = \sqrt{n(n+2)} = \sqrt{4(4+2)} = \sqrt{24} = 4.90 \text{ B.M}$$

$[\text{Mn}(\text{CN})_6]^{3-}$: d^2sp^3 hybridised



$$n = 2$$

$$\mu = \sqrt{2(2+2)} = \sqrt{8} = 2.83 \text{ B.M}$$

$$\text{Sum} = 4.90 + 2.83 = 7.73 \text{ B.M}$$

16. (2) : Octasaccharide $\xrightarrow{7\text{H}_2\text{O}}$ Ribose + 2-Deoxyribose + Glucose

$$\text{Mass of product} = 1024 + 7 \times 18 = 1150$$

$$\text{Mass of 2-deoxyribose} = 1150 \times \frac{58.26}{100} = 670 \text{ g}$$

$$\text{Mass of ribose + glucose} = 1150 - 670 = 480 \text{ g/mol}$$

Thus possible number of glucose unit is 1 and ribose unit is 2.



KEAM ENGINEERING

- The density of 3 M aqueous solution of a solute X is 1.86 g mL^{-1} . The molality of the solution is (molar mass of solute X is 120 g mol^{-1})
(a) 3 m (b) 4 m (c) 2 m (d) 5 m
(e) 1 m
- The Vividh Bharati station of All India Radio, Kozhikode, broadcasts on a frequency of 1500 kHz. What is the wavelength of the electromagnetic radiation emitted by transmitter? ($c = 3 \times 10^8 \text{ m s}^{-1}$)
(a) 200 m (b) 300 m (c) 100 m (d) 250 m
(e) 150 m
- Which of the following experimental phenomenon is explained by the wave nature of electromagnetic radiation?
(a) Black-body radiation
(b) Photoelectric effect
(c) Diffraction
(d) Variation of heat capacity of solids as a function of temperature
(e) Line spectra of atoms with reference to hydrogen
- Which of the following pair of oxides is neutral?
(a) Al_2O_3 and Na_2O (b) Al_2O_3 and As_2O_3
(c) Cl_2O_7 and Na_2O (d) Cl_2O_7 and Al_2O_3
(e) CO and N_2O
- The correct increasing order of dipole moment of NF_3 , H_2S , CHCl_3 and NH_3 molecules is
(a) $\text{NF}_3 < \text{H}_2\text{S} < \text{CHCl}_3 < \text{NH}_3$
(b) $\text{NH}_3 < \text{H}_2\text{S} < \text{CHCl}_3 < \text{NF}_3$
(c) $\text{NF}_3 < \text{CHCl}_3 < \text{H}_2\text{S} < \text{NH}_3$
(d) $\text{NH}_3 < \text{CHCl}_3 < \text{H}_2\text{S} < \text{NF}_3$
(e) $\text{CHCl}_3 < \text{H}_2\text{S} < \text{NF}_3 < \text{NH}_3$
- Choose the incorrect pair of molecule and its shape among the following:
(a) SF_4 See-saw
(b) BrF_5 Trigonal bipyramidal
(c) NH_3 Trigonal pyramidal
(d) XeF_4 Square planar
(e) ClF_3 T-shape
- In the reaction: $\frac{3}{2} \text{O}_{2(g)} \rightarrow \text{O}_{3(g)}$ the value of $\Delta_r G^\circ$ at 298 K is approximately
($K_p = 10^{-30}$ and $2.303RT = 5.7 \text{ kJ mol}^{-1}$)
(a) 171 kJ mol^{-1} (b) 191 kJ mol^{-1}
(c) -171 kJ mol^{-1} (d) -191 kJ mol^{-1}
(e) 100 kJ mol^{-1}
- Which of the following has least mean multiple bond enthalpy (in kJ mol^{-1}) at 298 K?
(a) $\text{N} \equiv \text{N}$ (b) $\text{C} \equiv \text{N}$ (c) $\text{C} = \text{C}$ (d) $\text{C} \equiv \text{O}$
(e) $\text{C} = \text{N}$
- Which of the following can act as Lewis acid?
(a) H_2O (b) HO^- (c) F^- (d) NH_3
(e) AlCl_3
- The concentration of hydrogen ions in a sample of soft drink is $2 \times 10^{-4} \text{ mol lit}^{-1}$. Its pH value is ($\log 2 = 0.3010$)
(a) 4.369 (b) 3.699 (c) 2.369 (d) 5.301
(e) 3.301
- Which of the following is the correct order of conductivity (in S m^{-1})?
(a) $\text{Fe} < \text{Na} < \text{Cu} < \text{Ag}$ (b) $\text{Fe} < \text{Cu} < \text{Na} < \text{Ag}$
(c) $\text{Ag} < \text{Na} < \text{Cu} < \text{Fe}$ (d) $\text{Ag} < \text{Cu} < \text{Na} < \text{Fe}$
(e) $\text{Na} < \text{Fe} < \text{Cu} < \text{Ag}$
- 'Layer Test' is used to identify
(a) bromide (b) fluoride
(c) potassium (d) water
(e) chloride
- Which of the following solvent has highest value of molal elevation constant, K_b ?
(a) Cyclohexane (b) Carbon disulphide
(c) Carbon tetrachloride (d) Acetic acid
(e) Chloroform

14. The initial concentration of N_2O_5 in the first order reaction, $\text{N}_2\text{O}_{5(g)} \rightarrow 2\text{NO}_{2(g)} + \frac{1}{2}\text{O}_{2(g)}$, was $1.68 \times 10^{-2} \text{ mol L}^{-1}$ at 310 K. The concentration of N_2O_5 after 10 minutes was $0.84 \times 10^{-2} \text{ mol L}^{-1}$. What is the rate constant of the reaction at 310 K? ($\log 2 = 0.3010$)
 (a) 0.0693 min^{-1} (b) 0.693 min^{-1}
 (c) 6.93 min^{-1} (d) 0.0639 min^{-1}
 (e) 0.0963 min^{-1}
15. Which of the following statement is not true about a catalyst?
 (a) It catalyses the spontaneous reactions.
 (b) A small amount of the catalyst can catalyse the large amount of reactants.
 (c) It does not alter the Gibbs energy of a reaction.
 (d) It catalyses the non-spontaneous reactions.
 (e) It does not change the equilibrium constant of a reaction.
16. The most common oxidation states of chromium are
 (a) +2, +7 (b) +3, +6
 (c) +2, +4 (d) +2, +5
 (e) +3, +5
17. Which of the following statement is true about potassium permanganate?
 (a) It is isostructural with KClO_3 .
 (b) It is paramagnetic in nature.
 (c) It oxidizes oxalates to carbon monoxide.
 (d) The structure of permanganate ion is square planar.
 (e) It is prepared by fusion of MnO_2 with an alkali metal hydroxide and an oxidising agent.
18. The type of sulphide formed by Lanthanoids is
 (a) LnS_3 (b) LnS_2
 (c) LnS (d) Ln_2S_3
 (e) Ln_2S
19. In which of the following compound, Mn has +7 oxidation state?
 (a) MnOF (b) MnO_2F
 (c) MnO_3F_2 (d) MnOF_2
 (e) MnO_3F
20. Which of the following is a heteroleptic complex?
 (a) $[\text{Co}(\text{NH}_3)_6]^{3+}$ (b) $[\text{Fe}(\text{CN})_6]^{4-}$
 (c) $[\text{Co}(\text{SCN})_4]^{2-}$ (d) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$
 (e) $[\text{Co}(\text{CN})_6]^{3-}$
21. Which of the following technique is used to separate chloroform and aniline?
 (a) Fractional distillation
 (b) Distillation under reduced pressure
 (c) Steam distillation
 (d) Continuous extraction
 (e) Distillation
22. In Kolbe's electrolytic method, when sodium acetate is electrolysed, the gases generated at anode are
 (a) ethane and H_2 (b) H_2 and CO_2
 (c) methane and ethane (d) ethane and CO_2
 (e) methane and H_2
23. The number of sigma (σ) and pi (π) bonds present in 3-methylbut-1-ene are respectively
 (a) 1 and 14 (b) 18 and 2
 (c) 16 and 2 (d) 17 and 1
 (e) 14 and 1
24. The order of reactivity of the following compounds towards $\text{S}_{\text{N}}2$ displacement reaction is
 (i) 2-bromo-2-methylbutane, (ii) 1-bromopentane, (iii) 2-bromopentane
 (a) (ii) > (i) > (iii) (b) (iii) > (i) > (ii)
 (c) (ii) > (iii) > (i) (d) (i) > (ii) > (iii)
 (e) (iii) > (ii) > (i)
25. The IUPAC name of phenyl isopentyl ether is
 (a) 3-methylbutoxybenzene
 (b) 2-methylbutoxybenzene
 (c) 2-methylphenoxybutane
 (d) 4-methylbutoxybenzene
 (e) 1-methylbutoxybenzene
26. Phenol on treatment with chloroform in the presence of NaOH , a $-\text{CHO}$ group is introduced at *ortho* position of benzene ring. The reaction is known as
 (a) Kolbe's reaction
 (b) Reimer-Tiemann reaction
 (c) Gattermann-Koch reaction
 (d) Stephen reaction
 (e) Sandmeyer reaction
27. Toluene on treatment with chromic oxide in presence of acetic anhydride at 273 - 283 K gives compound (X). Compound (X) on hydrolysis with aqueous acid gives compound (Y). The compounds (X) and (Y) are respectively
 (a) benzylidene diacetate and phenol
 (b) benzylalcohol and benzene
 (c) benzylidene diacetate and benzaldehyde
 (d) benzene and phenol
 (e) benzaldehyde and phenol

- 28.** Fehling's reagent is a mixture of
 (a) aqueous CuSO_4 and ammonical AgNO_3 solution
 (b) aqueous CuSO_4 and 2,4-DNP
 (c) aqueous KOH and ammonical AgNO_3 solution
 (d) aqueous CuSO_4 and alkaline sodium potassium tartarate
 (e) aqueous KOH and alkaline sodium potassium tartarate
- 29.** The order of basic strength of following amines is
 (i) CH_3NH_2 (ii) $(\text{C}_2\text{H}_5)_2\text{NH}$
 (iii) $\text{C}_6\text{H}_5\text{NH}_2$ (iv) $\text{C}_6\text{H}_5\text{NHCH}_3$
 (a) (ii) < (i) < (iv) < (iii)
 (b) (iii) < (iv) < (ii) < (i)
 (c) (ii) < (iii) < (iv) < (i)
 (d) (i) < (ii) < (iii) < (iv)
 (e) (iii) < (iv) < (i) < (ii)
- 30.** The disease caused by the deficiency of riboflavin is
 (a) cheilosis (b) rickets (c) beri beri (d) scurvy
 (e) xerophthalmia

SOLUTIONS

1. (c): Given, molarity = 3 M
 Density = 1.86 g mL^{-1}
 Molar mass of solute, $X = 120 \text{ g mol}^{-1}$
 Mass of solute X in 1 L solution = $3 \times 120 = 360 \text{ g}$
 We know that, density = $\frac{\text{Mass of solution}}{\text{Volume of solution}}$

$$1.86 = \frac{\text{Mass of solution}}{1000 \text{ ml}}$$

 Mass of solution = $1.86 \times 1000 = 1860 \text{ g}$
 Mass of solvent = $1860 - 360 = 1500 \text{ g} = 1.5 \text{ kg}$
 Number of moles of solute = $\frac{360}{120} = 3 \text{ mol}$
 Molality = $\frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$

$$\text{Molality} = \frac{3 \text{ mol}}{1.5 \text{ kg}} = 2 \text{ m}$$

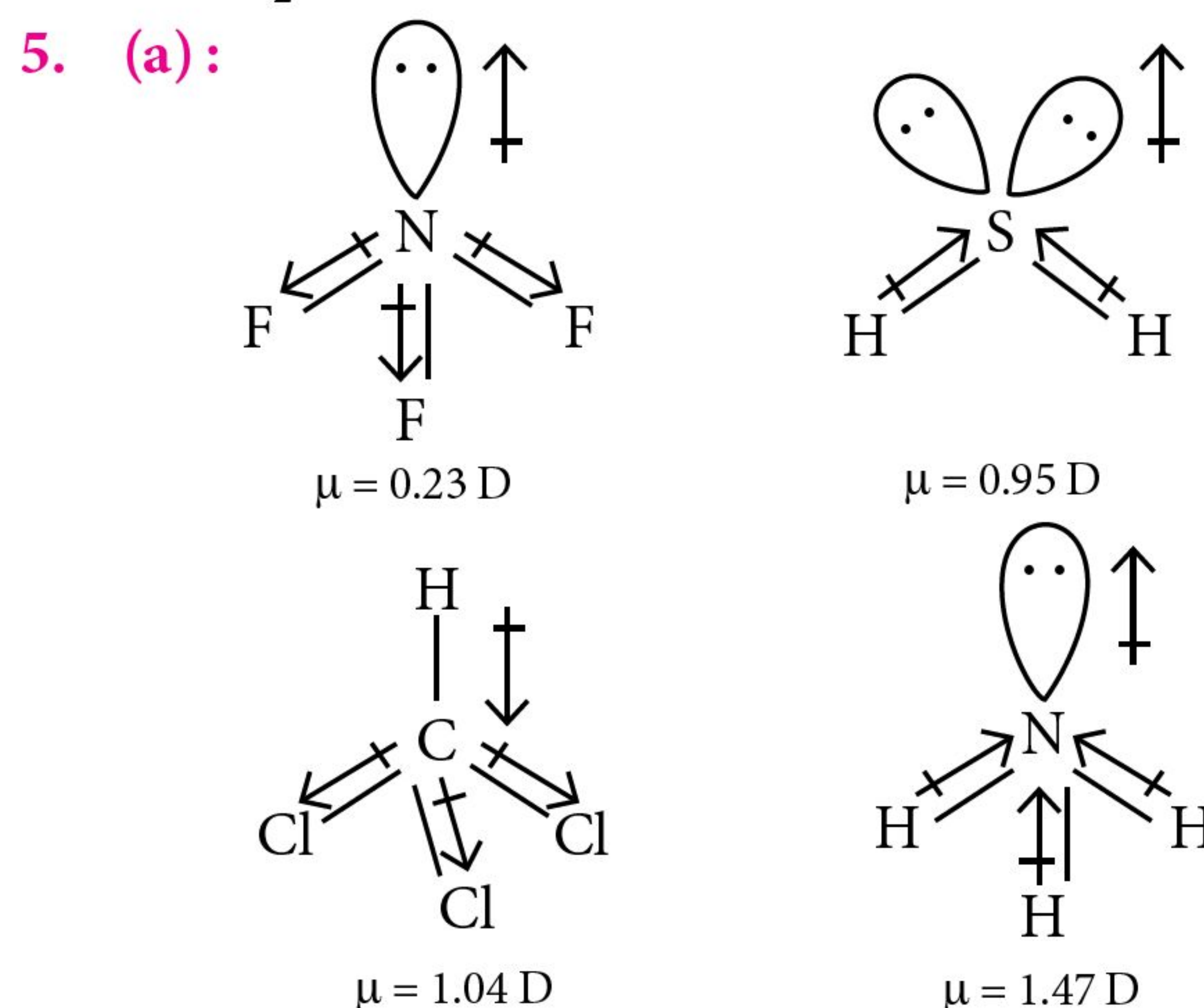
2. (a): Given, frequency (ν) = 1500 kHz
 $= 1500 \times 10^3 \text{ Hz}$

$c = 3 \times 10^8 \text{ m s}^{-1}$
 We know that, $c = \lambda \nu$
 $3 \times 10^8 = \lambda \times 1500 \times 10^3 \text{ s}^{-1}$

$$\Rightarrow \lambda = \frac{3 \times 10^8}{15 \times 10^5} = \frac{1}{5} \times 10^3 = 200 \text{ m}$$

3. (c): Phenomenon such as diffraction and interference can be explained by the wave nature of the electromagnetic radiation.

4. (e): Metallic oxides are generally basic and non-metallic oxides are generally acidic in nature. CO and N_2O are neutral oxides.



According to experimental values, the increasing order of dipole moment is $\text{NF}_3 < \text{H}_2\text{S} < \text{CHCl}_3 < \text{NH}_3$

(b): Molecule	Shape
SF_4	See-saw
BrF_5	Square pyramidal
NH_3	Trigonal pyramidal
XeF_4	Square planar
ClF_3	T-shape

7. (a): Given, $\frac{3}{2} \text{O}_{2(g)} \rightarrow \text{O}_{3(g)}$, $K_p = 10^{-30}$
 $2.303RT = 5.7 \text{ kJ mol}^{-1}$
 We know that, $\Delta_r G^\circ = -2.303RT \log K_p$
 $\Delta_r G^\circ = -5.7 \times \log 10^{-30} = 5.7 \times 30 = 171 \text{ kJ mol}^{-1}$

(c): Multiple Bonds	Mean multiple bond enthalpy (kJ mol^{-1}) at 298 K
$\text{N} \equiv \text{N}$	946
$\text{C} \equiv \text{N}$	891
$\text{C} = \text{C}$	611
$\text{C} \equiv \text{O}$	1070
$\text{C} = \text{N}$	615

9. (e): Electron deficient species act as Lewis acid.

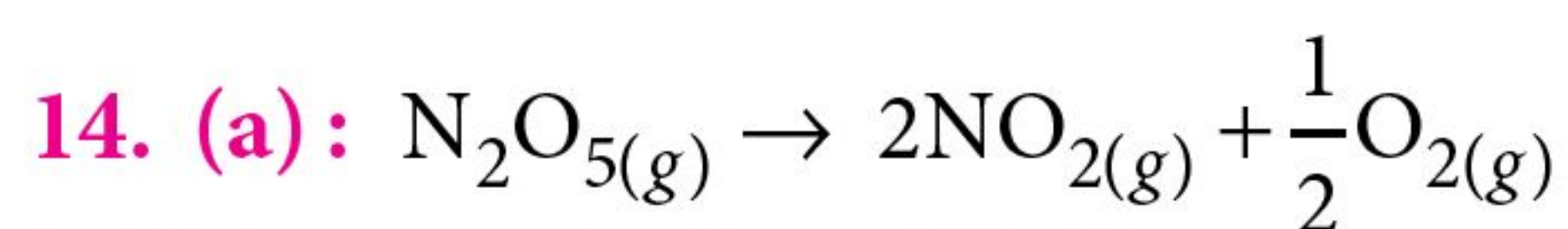
10. (b): Given : $[\text{H}^+] = 2 \times 10^{-4} \text{ mol L}^{-1}$
 $\text{pH} = -\log[\text{H}^+]$
 $\text{pH} = -\log(2 \times 10^{-4}) = -[\log(2) + \log(10^{-4})]$
 $= -(0.3010 - 4) = 4 - 0.3010 = 3.699$

(a): Material	Conductivity (S m^{-1}) at 298 K
Fe	1.0×10^3
Na	2.1×10^3
Cu	5.9×10^3
Ag	6.2×10^3

So, the increasing order of conductivity is $\text{Fe} < \text{Na} < \text{Cu} < \text{Ag}$

12. (a): Layer test is used to identify the presence of iodide and bromide ions.

13. (c) : Solvent	K_b (K kg mol⁻¹)
Cyclohexane	2.79
Carbon disulphide	2.34
Carbon tetrachloride	5.03
Acetic acid	2.93
Chloroform	3.63



Initial concentration of N_2O_5 ,

$$[\text{N}_2\text{O}_5]_0 = 1.68 \times 10^{-2} \text{ mol L}^{-1}$$

Concentration of N_2O_5 after 10 min,

$$[\text{N}_2\text{O}_5]_t = 0.84 \times 10^{-2} \text{ mol L}^{-1}$$

Applying the formula, $k = \frac{2.303}{t} \log \frac{[\text{N}_2\text{O}_5]_0}{[\text{N}_2\text{O}_5]_t}$

$$k = \frac{2.303}{10} \log \frac{(1.68 \times 10^{-2})}{(0.84 \times 10^{-2})}$$

$$= \frac{2.303}{10} \times 0.3010 = 0.0693 \text{ min}^{-1}$$

15. (d) : Catalysts does not catalyse non-spontaneous reactions.

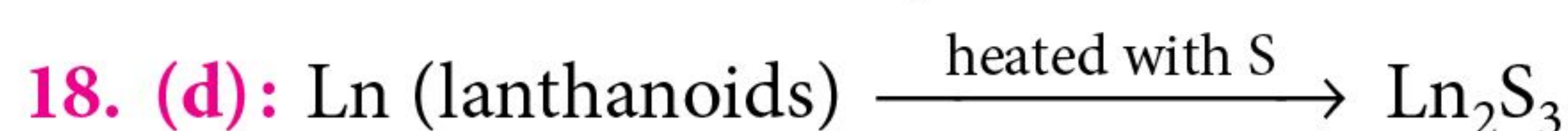
16. (b) : The most common oxidation states of chromium are +3, +6.

17. (e) : • Potassium permanganate is isostructural with KClO_4 .

• KMnO_4 is diamagnetic along with temperature dependent weak paramagnetism.

• KMnO_4 oxidises oxalates to carbon dioxide.

• The structure of KMnO_4 is tetrahedral.

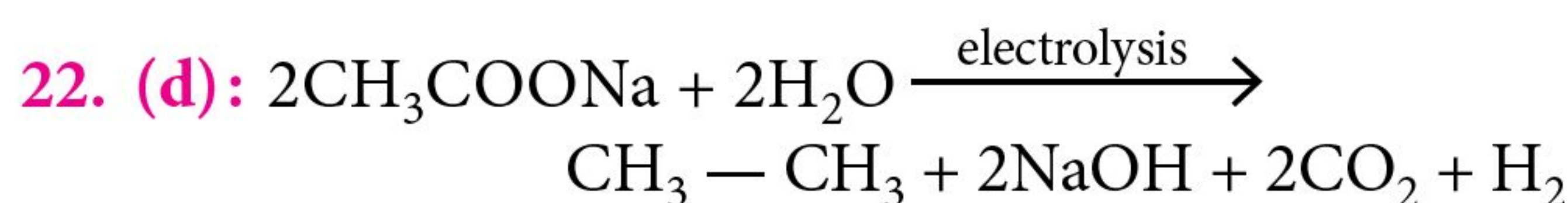


19. (e) : Mn has +7 oxidation state in MnO_3F .

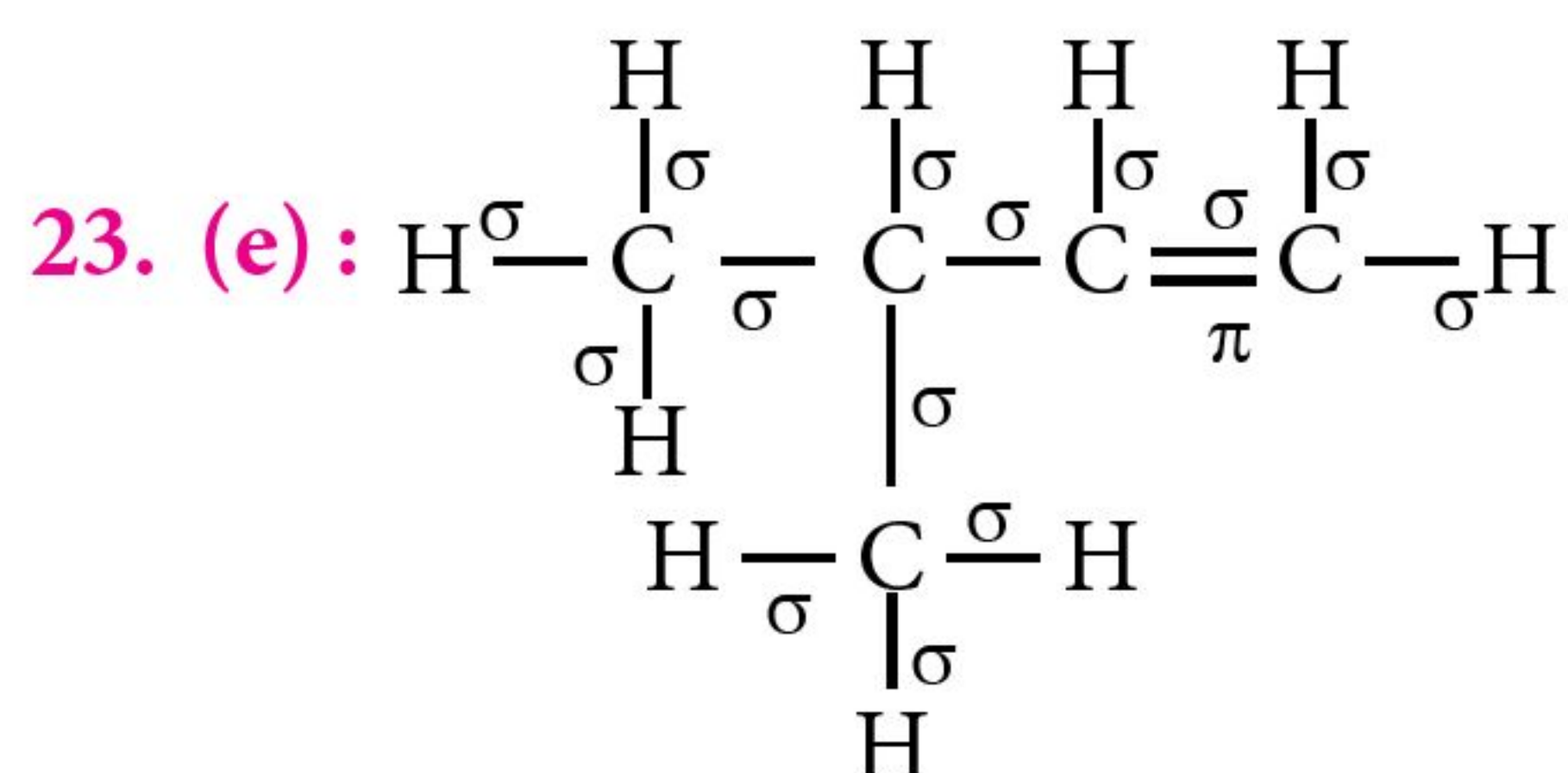
$$x + 3(-2) + (-1) = 0 \Rightarrow x = +7$$

20. (d) : Complexes in which a metal atom or ion is bound to more than one kind of donor groups, e.g., $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$, are known as heteroleptic complex.

21. (e) : Distillation is used to separate chloroform and aniline.



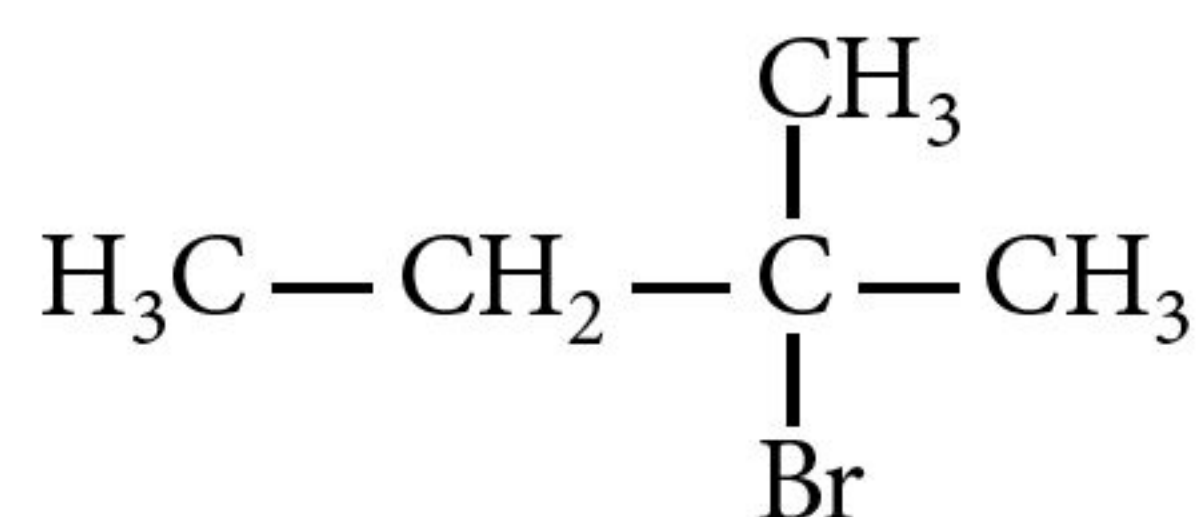
Reaction at anode : $2\text{CH}_3\text{COO}^- - 2e^- \rightarrow \text{C}_2\text{H}_6 + 2\text{CO}_2 \uparrow$
 Ethane



Number of sigma (σ) bonds = 14

Number of pi (π) bond = 1

24. (c) : Order of reactivity of alkyl halides towards $\text{S}_{\text{N}}2$ reaction is $1^\circ > 2^\circ > 3^\circ$.



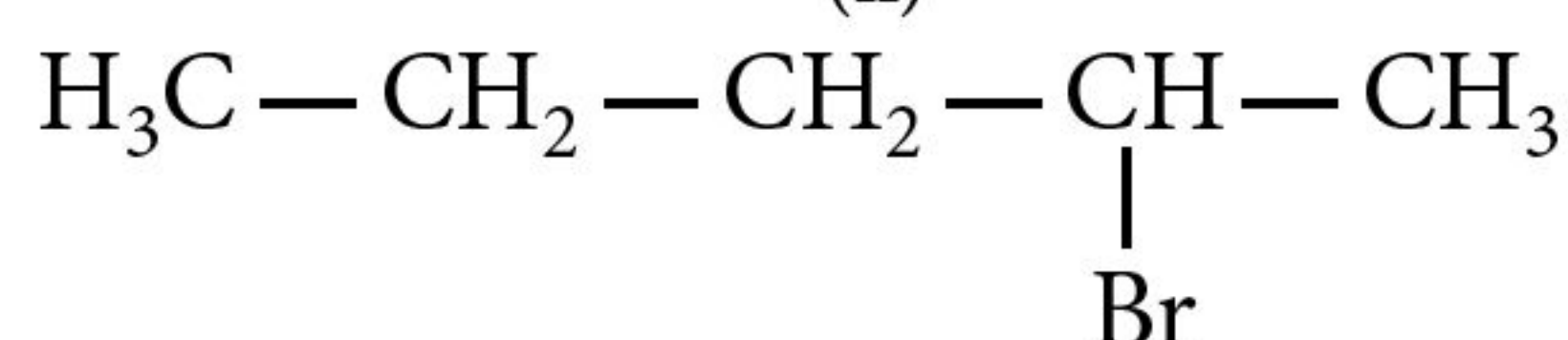
2-Bromo-2-methyl butane (3°)

(i)



1-Bromopentane (1°)

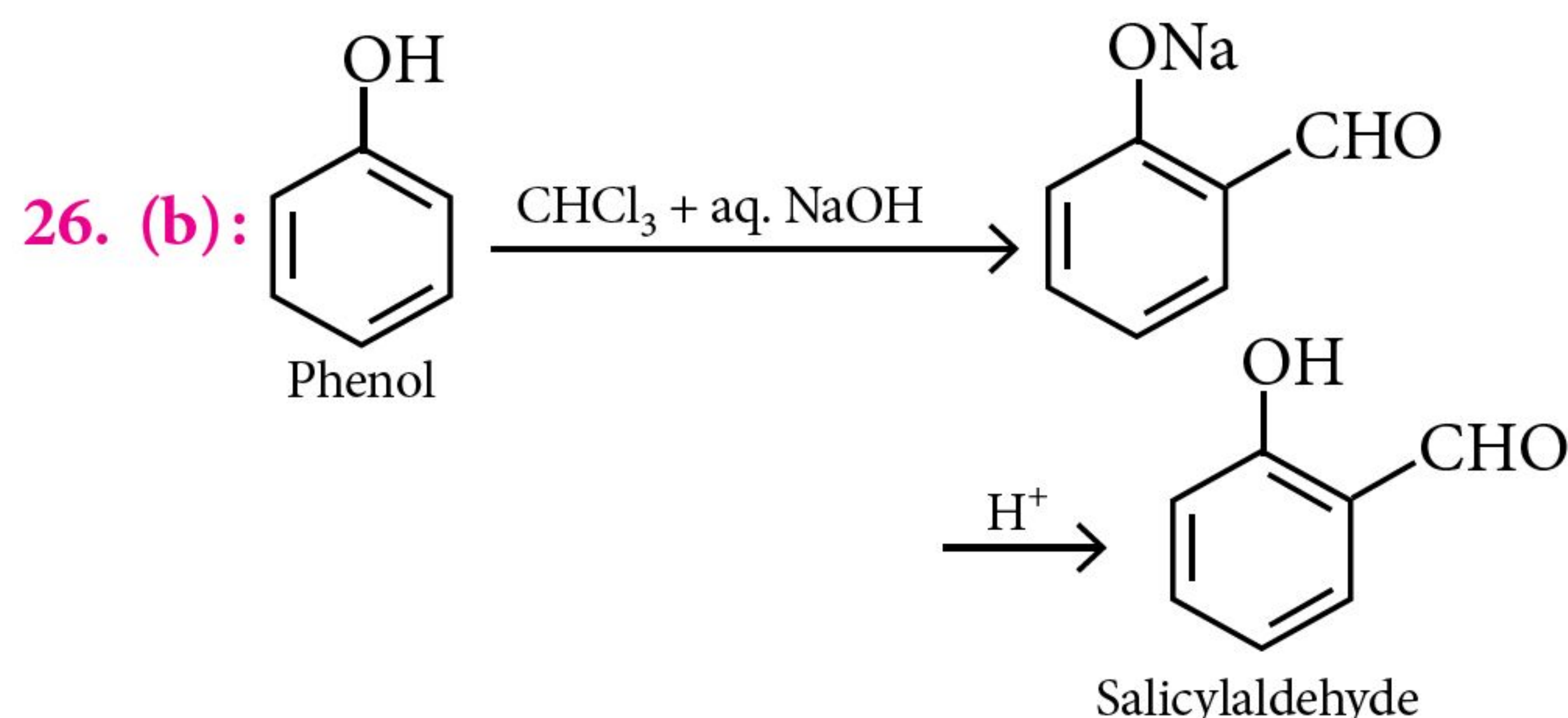
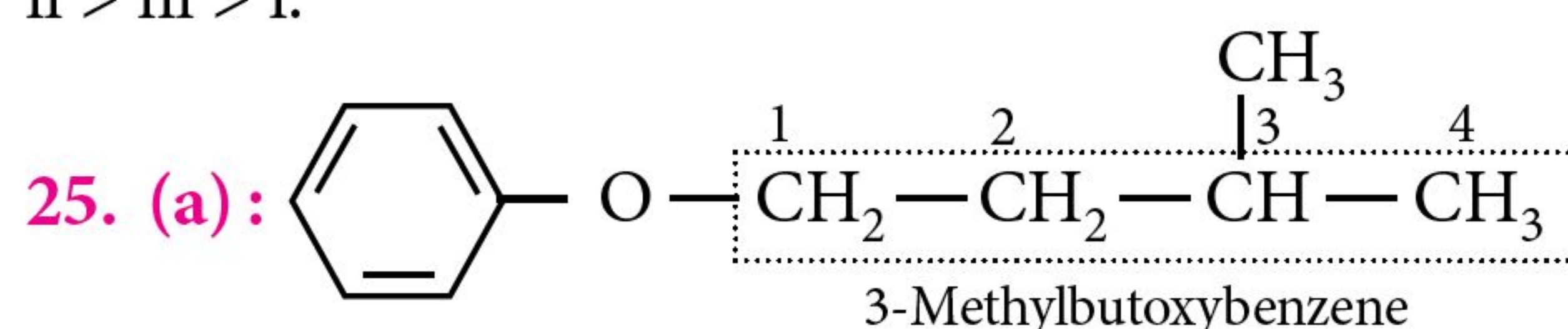
(ii)



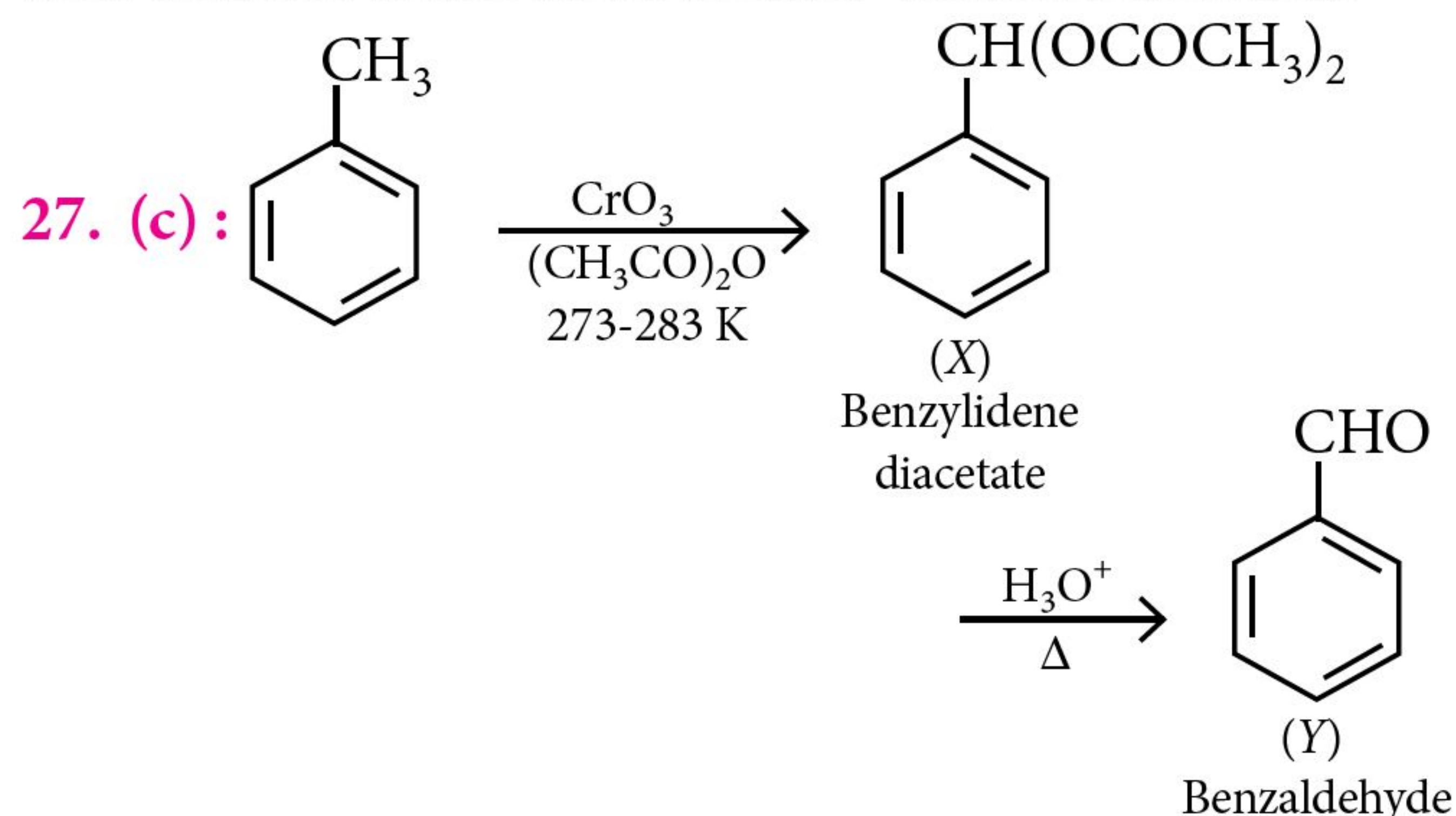
2-Bromopentane (2°)

(iii)

So, the correct order of reactivity towards $\text{S}_{\text{N}}2$ reaction is $\text{ii} > \text{iii} > \text{i}$.

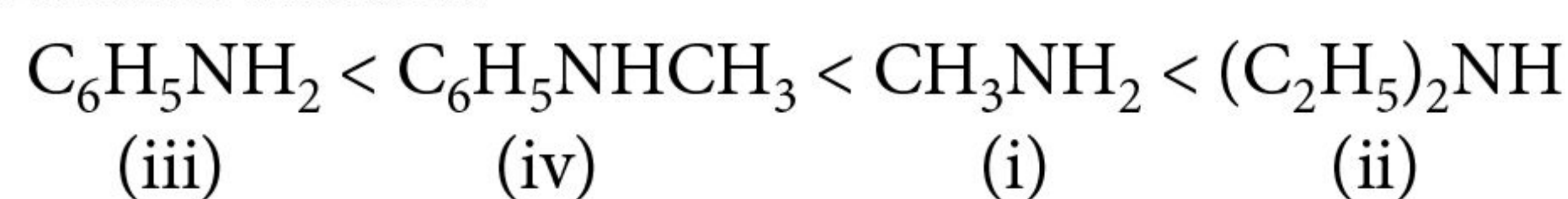


This reaction is known as Reimer-Tiemann reaction.



28. (d) : Fehling's reagent is a mixture of aqueous copper sulphate and alkaline sodium potassium tartarate.

29. (e) : Aliphatic amines are stronger bases than aromatic amines.



30. (a) : The disease caused by the deficiency of vitamin B₂ (riboflavin) is cheilosis.



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Unit 1

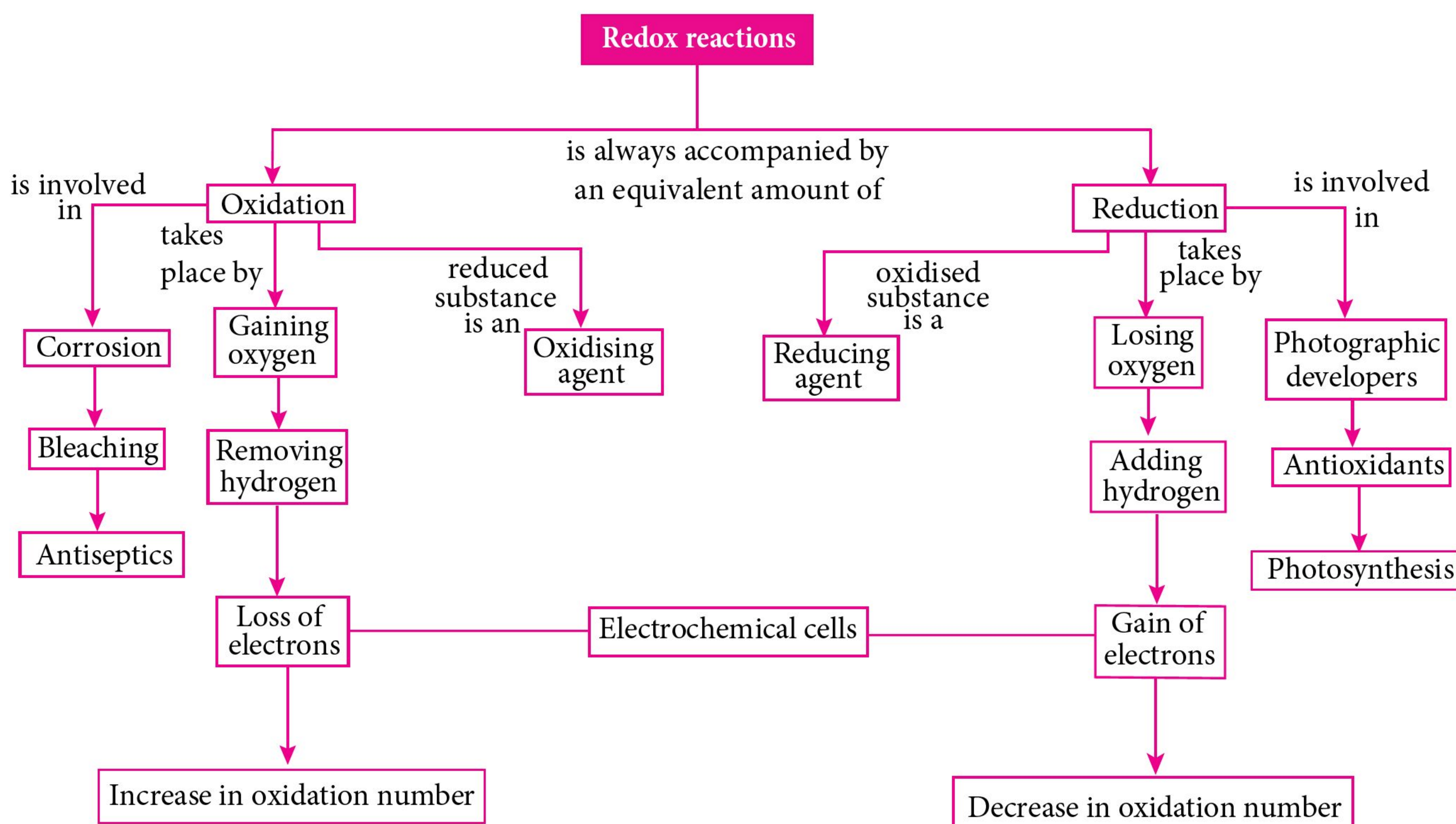
Redox Reactions | Hydrogen

REDOX REACTIONS

INTRODUCTION

According to old concept, the process of addition of oxygen or removal of hydrogen from a substance is called as oxidation. While the reverse process of addition of hydrogen or removal of oxygen from a substance is called as reduction.

Oxidation and reduction reactions take place simultaneously and the overall process is called as redox reaction.



OXIDATION-REDUCTION

Oxidation

There are number of ways to define oxidation :

- Electrons are lost from an atom or ion
e.g., $\text{Na} \rightarrow \text{Na}^+ + e^-$
 $\text{Sn}^{2+} \rightarrow \text{Sn}^{4+} + 2e^-$
- Involves addition of oxygen.
e.g., $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$ (C is oxidised to CO_2)
- Removal of hydrogen is also known as oxidation.
e.g., $\text{H}_2\text{S} + \text{Cl}_2 \rightarrow 2\text{HCl} + \text{S}$ (H_2S is oxidised to S)
- Addition of any electronegative element.
e.g., $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$ (Na is oxidised)
- Removal of any electropositive element.
e.g., $\text{K}_4[\text{Fe}(\text{CN})_6] \rightarrow \text{K}_3[\text{Fe}(\text{CN})_6]$ (Fe is oxidised)

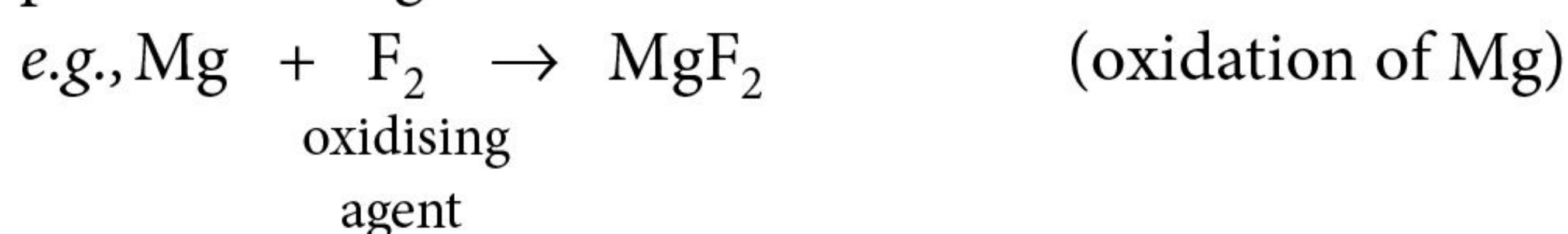
Reduction

Reduction is also defined in number of ways :

- An atom or ion gains one or more electrons.
e.g., $\text{Cl}_2 + 2e^- \rightarrow 2\text{Cl}^-$;
 $[\text{Fe}(\text{CN})_6]^{3-} + e^- \rightarrow [\text{Fe}(\text{CN})_6]^{4-}$
- Involves removal of oxygen.
e.g., $\text{CuO} + \text{H}_2 \rightarrow \text{Cu} + \text{H}_2\text{O}$ (CuO is reduced to Cu)
- Addition of hydrogen is also known as reduction.
e.g., $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$ (Cl_2 is reduced to HCl)
- Removal of any electronegative element.
e.g., $\text{FeCl}_3 \rightarrow \text{FeCl}_2$ (reduction of Fe)
- Addition of electropositive element.
e.g., $\text{HgCl}_2 + \text{Hg} \rightarrow \text{Hg}_2\text{Cl}_2$ (reduction of Hg)

OXIDISING AGENT (OXIDANT)

Oxidising agent oxidises other substances and in the process itself gets reduced.

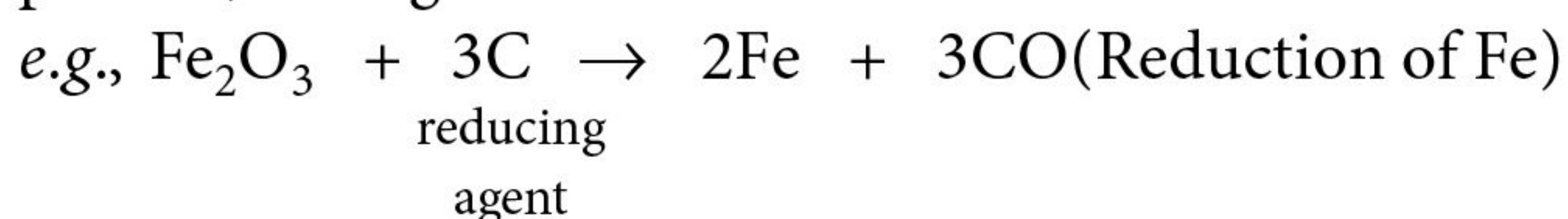


Some Important Oxidising Agents

- Molecules of highly electronegative elements, *e.g.*, O_2 , O_3 and X_2 (halogens). Fluorine is the strongest oxidising agent.
- Oxides of few elements, *e.g.*, MgO , CuO , CrO_3 , P_4O_{10} , CO_2 , etc.
- Compounds containing an element in higher oxidation state, *e.g.*, KMnO_4 , $\text{Na}_2\text{Cr}_2\text{O}_7$, $\text{K}_2\text{Cr}_2\text{O}_7$, CrO_3 , NaNO_3 , HNO_3 , H_2SO_4 , KClO_4 , FeCl_3 , HgCl_2 , SO_3 , H_2O_2 , etc.

REDUCING AGENT (REDUCTANT)

Reducing agent reduces other substances and in the process, itself gets oxidised.



Some Important Reducing Agents

- All metals, *e.g.*, Li, Na, Zn, Fe, Al etc. Lithium is the strongest reducing agent in solution.
- A few non-metals, *e.g.*, C, H, S, etc.
- Compounds containing an element in the lower oxidation state, *e.g.*, FeCl_2 , FeSO_4 , Cu_2O , Hg_2Cl_2 , SnCl_2 , etc.
- Organic compounds like HOOC-COOH and HCOOH , etc.
- Few hydrides, *e.g.*, HCl , HBr , HI , H_2S , etc.
- Metallic hydrides, *e.g.*, NaH , LiH , etc.

OXIDATION NUMBER

Oxidation number of an element is defined as the charge which an atom of the element has in its ion or in combined state with other atoms. Oxidation number can also be defined as the number of electrons which the atom of an element loses or gains in going from its natural free state to a particular compound or ion. Oxidation number is also called oxidation state. It can be positive, negative, zero or even fraction.

Rules for Calculation of Oxidation Number

- Oxidation number of atoms in their elemental state or allotropic state is zero, *e.g.*, H_2 , Cl_2 , N_2 , O_2 , O_3 , C, Na, P, Zn, Ag, etc.
- For monoatomic ions, oxidation number is same as the charge on it.
e.g., Na^+ ; oxidation number = + 1
 Mg^{2+} ; oxidation number = + 2
 Cl^- ; oxidation number = - 1
 S^{2-} ; oxidation number = - 2, etc.
- Oxidation number of hydrogen is +1 in all its compounds except metallic hydrides, *e.g.*, NaH , CaH_2 , etc., where it is -1.
- Oxidation number of oxygen is -2 in all its compounds with few following exceptions :
In peroxides *e.g.*, H_2O_2 , Na_2O_2 , BaO_2 etc.
oxidation state of oxygen is -1
In superoxides *e.g.*, KO_2 oxidation state of oxygen is $-\frac{1}{2}$

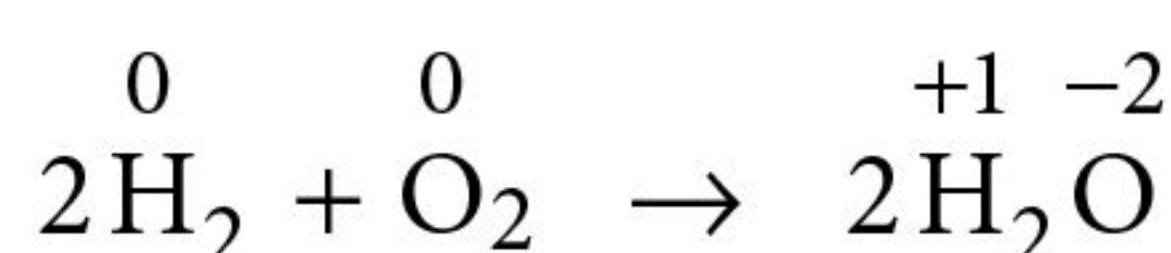
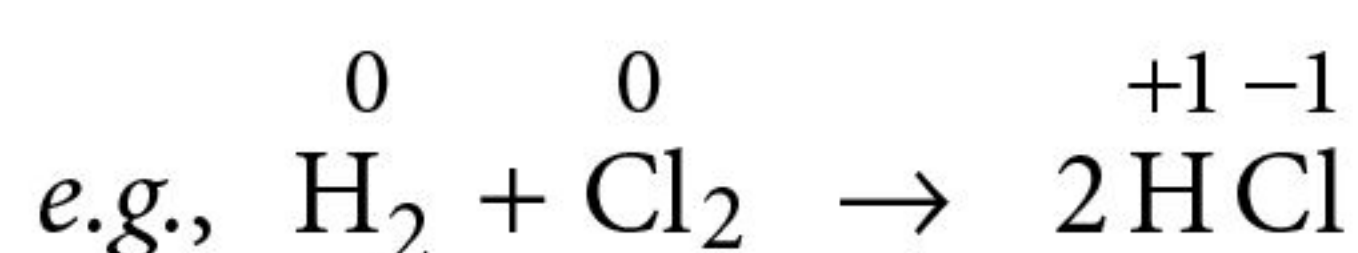
In oxygen fluoride (OF₂) oxidation state of oxygen is +2

In ozonides e.g., KO₃ oxidation state of oxygen is -1/3

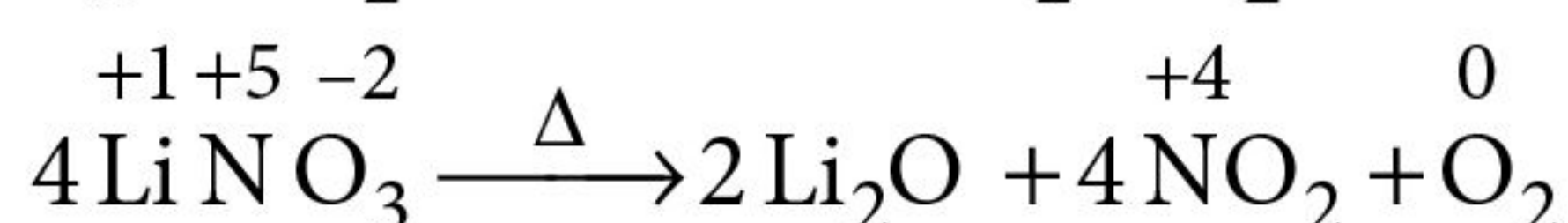
- Oxidation number of fluorine is always -1.
- In metal halides, oxidation number of halogens is -1. e.g., NaCl, oxidation number of Cl = -1.
- In sulphides, oxidation number of sulphur is -2 e.g., Na₂S, oxidation number of S = -2.
- Oxidation number of alkali metals (e.g., Li, Na, K etc.) and alkaline earth metals (e.g., Mg, Ca, etc.) is always +1 and +2 respectively.
- Oxidation number of metal in metal carbonyl complexes and amalgam is always zero. e.g., in [Ni(CO)₄], oxidation number of Ni is zero.
- Oxidation number of N is -3 when it is bonded to less electronegative atom, e.g., NH₃. Whereas, oxidation number of N is +3 when it is bonded to more electronegative atom, e.g., NF₃.
- In interhalogen compounds more electronegative halogen has an oxidation number of -1. e.g., in IF₇ oxidation number of F is -1 and oxidation number of I = +7, in ICl₃ oxidation number of Cl = -1, oxidation number of I = +3.
- Sum of oxidation number of all the atoms in a compound is equal to the charge on the compound.
- The maximum oxidation number of an element is equal to number of valence electrons of its atom and minimum oxidation number is equal to the number of electrons required to attain the noble gas configuration. (zero for neutral compounds).

TYPES OF REDOX REACTIONS

- **Combination Reaction :** These are the reactions in which two atoms or molecules combine together to form a third molecule.



- **Decomposition Reaction :** These are the reactions in which a molecule breaks down to form two or more atoms or molecules. For these reactions to be redox reaction one of the products must be in elemental state.

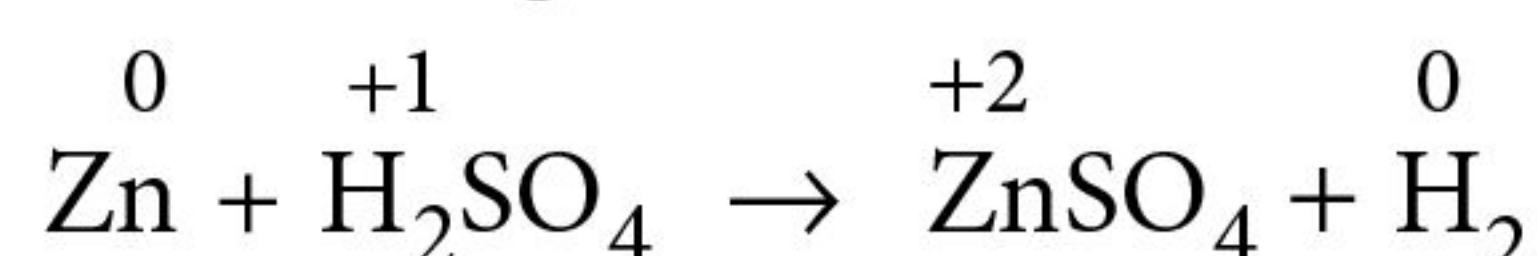


- **Displacement Reaction :** These are the reactions in which an atom or ion in a compound is replaced by another atom or ion. These reactions are represented as, $AB + C \rightarrow AC + B$

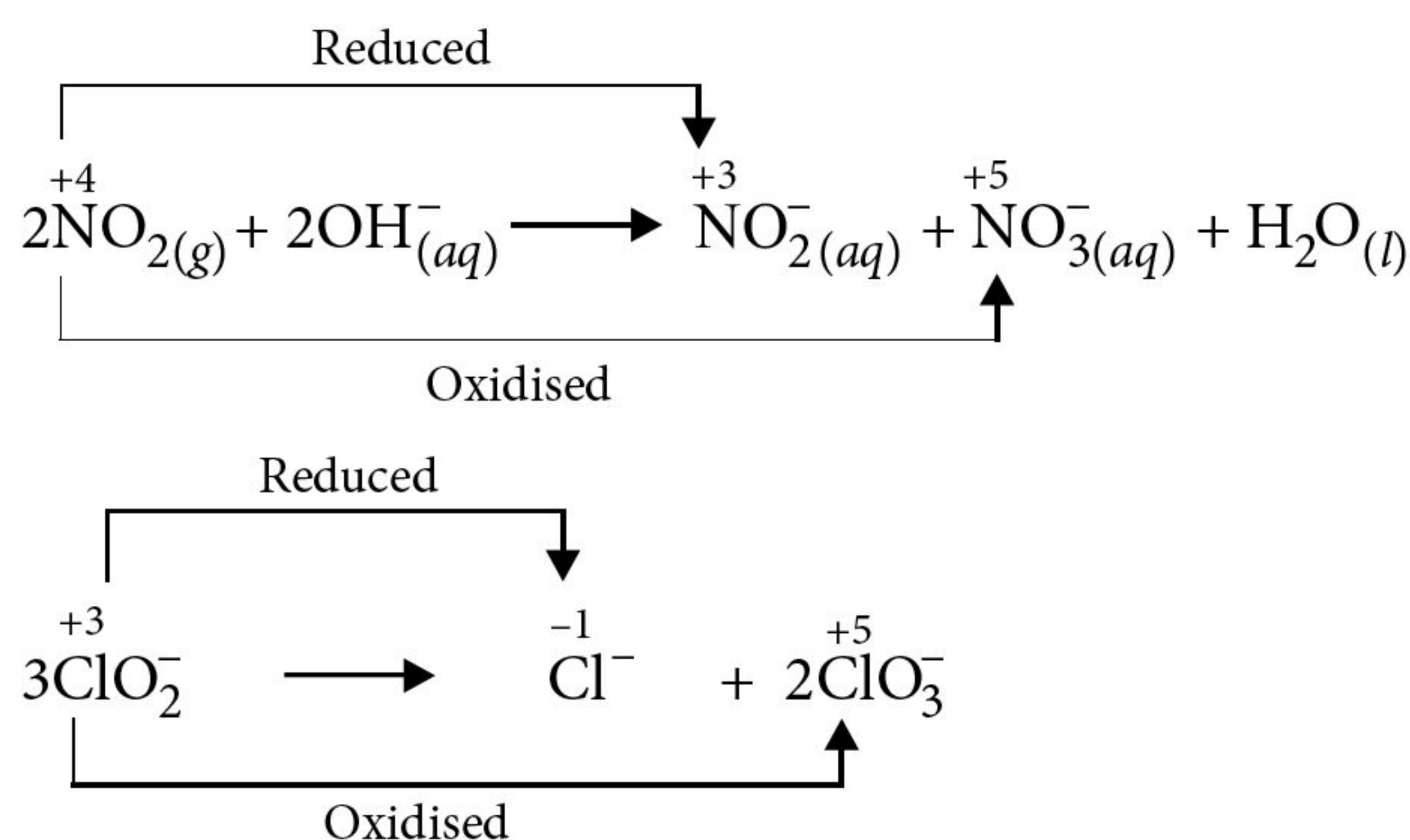
If a metal atom/ion is displaced in the reaction, it is called metal displacement reaction e.g.,



If a non-metal atom/ion is displaced in the reaction, the reaction is called non-metal displacement reaction e.g.,



- **Disproportionation Reaction :** These are the reactions in which a single species is oxidised as well as reduced simultaneously. In these reactions, the reacting species must have an element which can have three variable oxidation states.



BALANCING OF REDOX REACTIONS

Chemical equation can be balanced by different methods :

1. Hit and trial
2. Partial equation
3. Ion-electron
4. Oxidation number

To balance chemical equations for redox processes, ion-electron method and oxidation number method are used.

Ion-electron Method or Half Equation Method

In this method, two half equations viz. oxidation half reaction and reduction half reaction are balanced separately and then combined together to give net balanced redox equation. The main steps involved in the balancing of redox equations by ion electron method are :

Step 1 : Write the skeletal equation in ionic form and indicate oxidation number of all the elements which appear in the equation above their respective symbols.

Step 2 : Find out the species which undergo a change in their oxidation number.

Step 3 : Split the skeletal equation into two half reactions *i.e.*, oxidation half reaction and reduction half reaction.

Step 4 : Balance the atoms other than O and H in each half reaction individually.

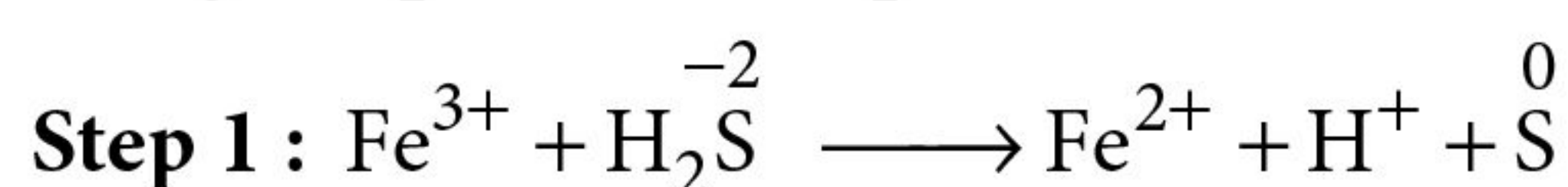
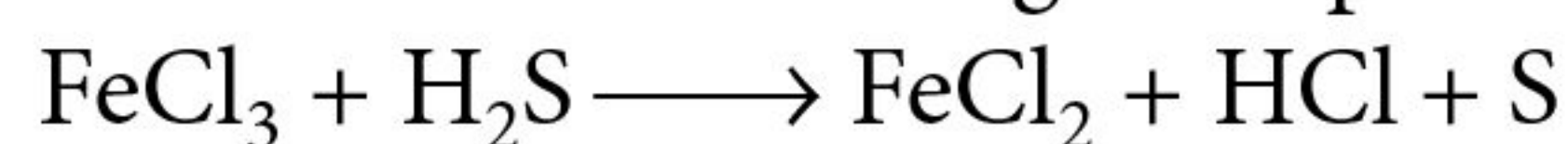
Step 5 : Add electrons to whatever side is necessary to make up the difference in oxidation number in each half reaction.

- Balance charge by adding H^+ ions if the reaction occurs in the acidic medium and by adding OH^- ions if the reaction occurs in the basic medium.
- Balance oxygen atom by adding suitable number of H_2O molecules to the side deficient in O atoms.

Step 6 : The two half reactions are multiplied by suitable numbers so that total number of electrons lost in oxidation half reaction is equal to total number of electrons gained in reduction half reaction or *vice-versa*. After this, the two equations are added up.

Step 7 : The total charge on both sides of equation must be equal, this is checked to verify that the final equation obtained is balanced or not.

Consider the following examples :



Step 2 : Oxidation number of Fe decreases from +3 to +2. Oxidation number of S increases from -2 to 0.

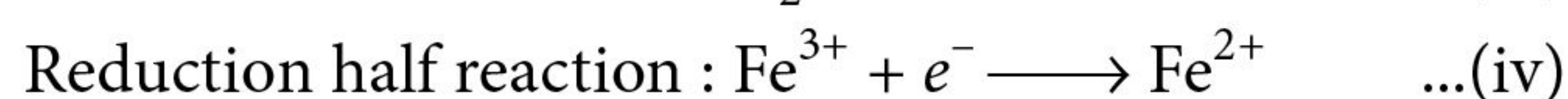
Step 3 : Oxidation half reaction :



Reduction half reaction :

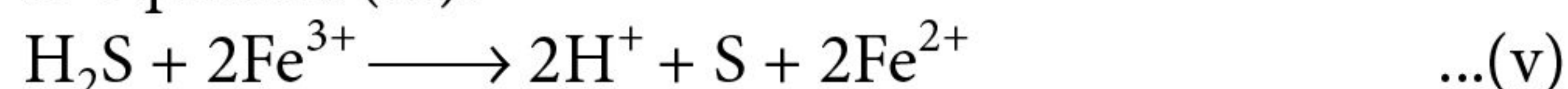


Step 4 : Addition of electrons to balance oxidation number.



No need to add H^+ or OH^- as charge is already balanced.

Step 5 : Multiply equation (iv) by 2 and add the resultant to equation (iii).



Step 6 : Total charge on L.H.S of equation (v)

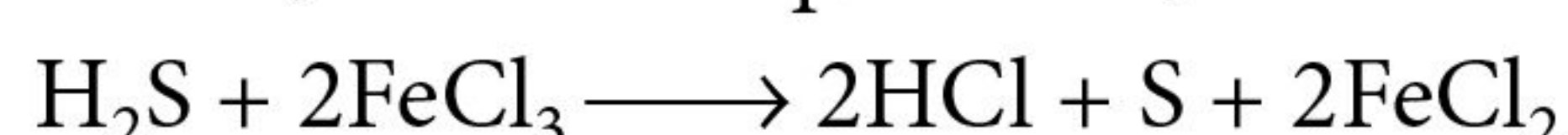
$$= 2 \times (+1) + 1 \times (-2) + 2(+3) = +6$$

Total charge on R.H.S of equation (v)

$$= 2 \times (+1) + 1 \times 0 + 2(+2) = +6$$

Since, the total charge on L.H.S is equal to that on R.H.S. therefore, equation (v) represents correct balanced redox equation.

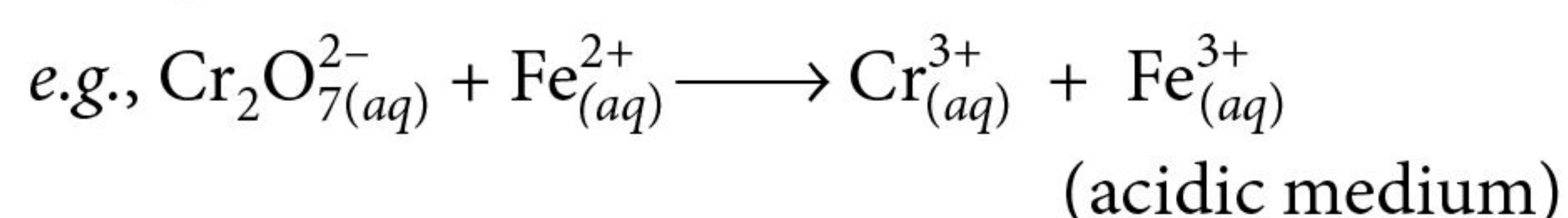
Hence, balanced equation is,



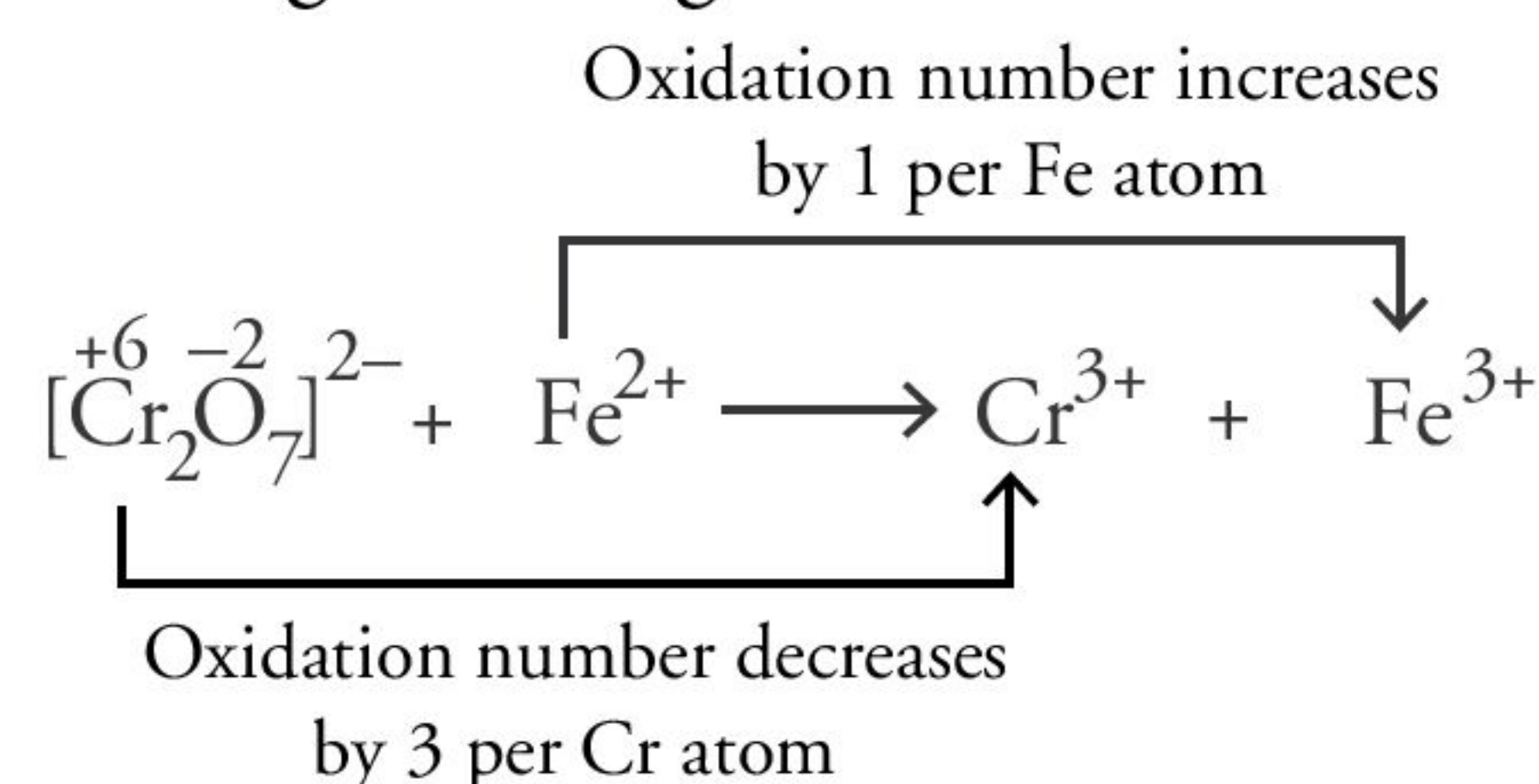
Oxidation Number Method

Let us discuss various steps of the method with an example.

- Write the skeletal equation representing the chemical change



- Indicate the oxidation number of each element above its symbol and identify the elements which undergo a change in oxidation number.



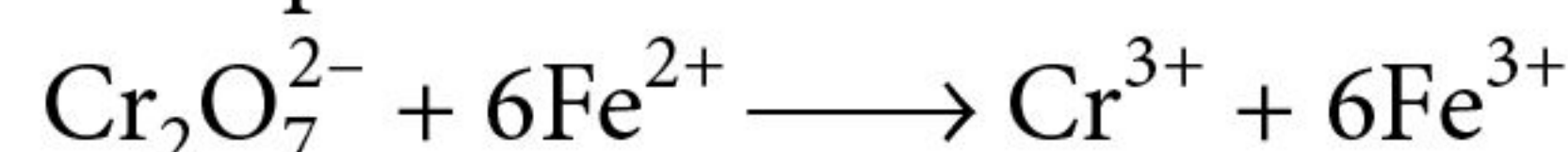
- Calculate total increase and decrease in oxidation number.

$$\text{Total increase in oxidation number} = 1$$

$$\text{Total decrease in oxidation number} = 3 \times 2 = 6$$

- Equalise the total increase and decrease in oxidation number by multiplying the oxidant and reductant with suitable integers.

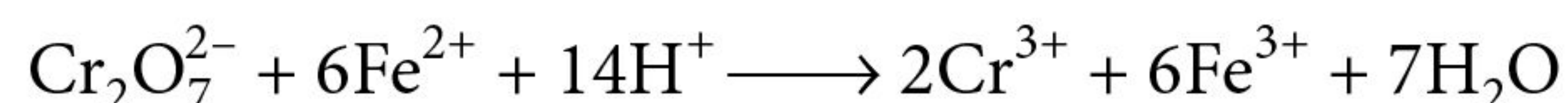
Total increase in oxidation number is 1 and decrease is 6, therefore, Fe on both sides should be multiplied with 6.



- Balance all atoms other than hydrogen and oxygen



- Finally balance O and H by adding H_2O and H^+ for the acidic medium reaction and by adding H_2O and OH^- for the basic medium reaction to the side which is deficient in O and H.

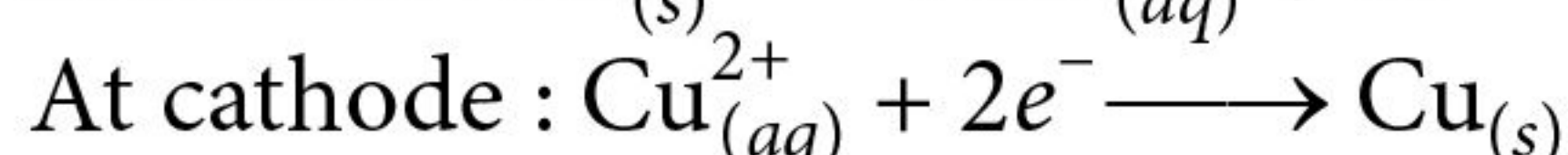
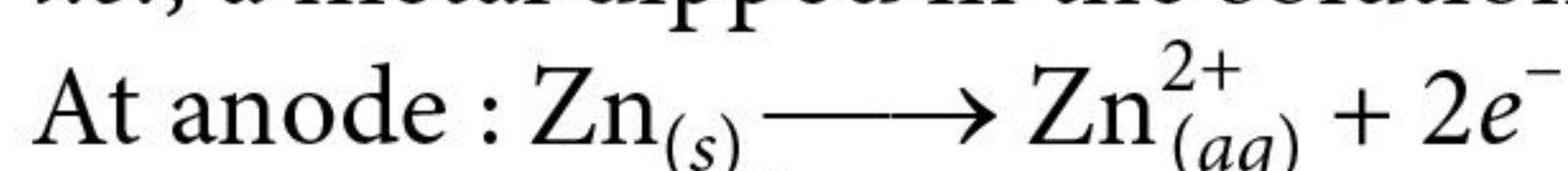


Charge on both sides would be automatically balanced.

REDOX REACTIONS AND ELECTRODE PROCESSES

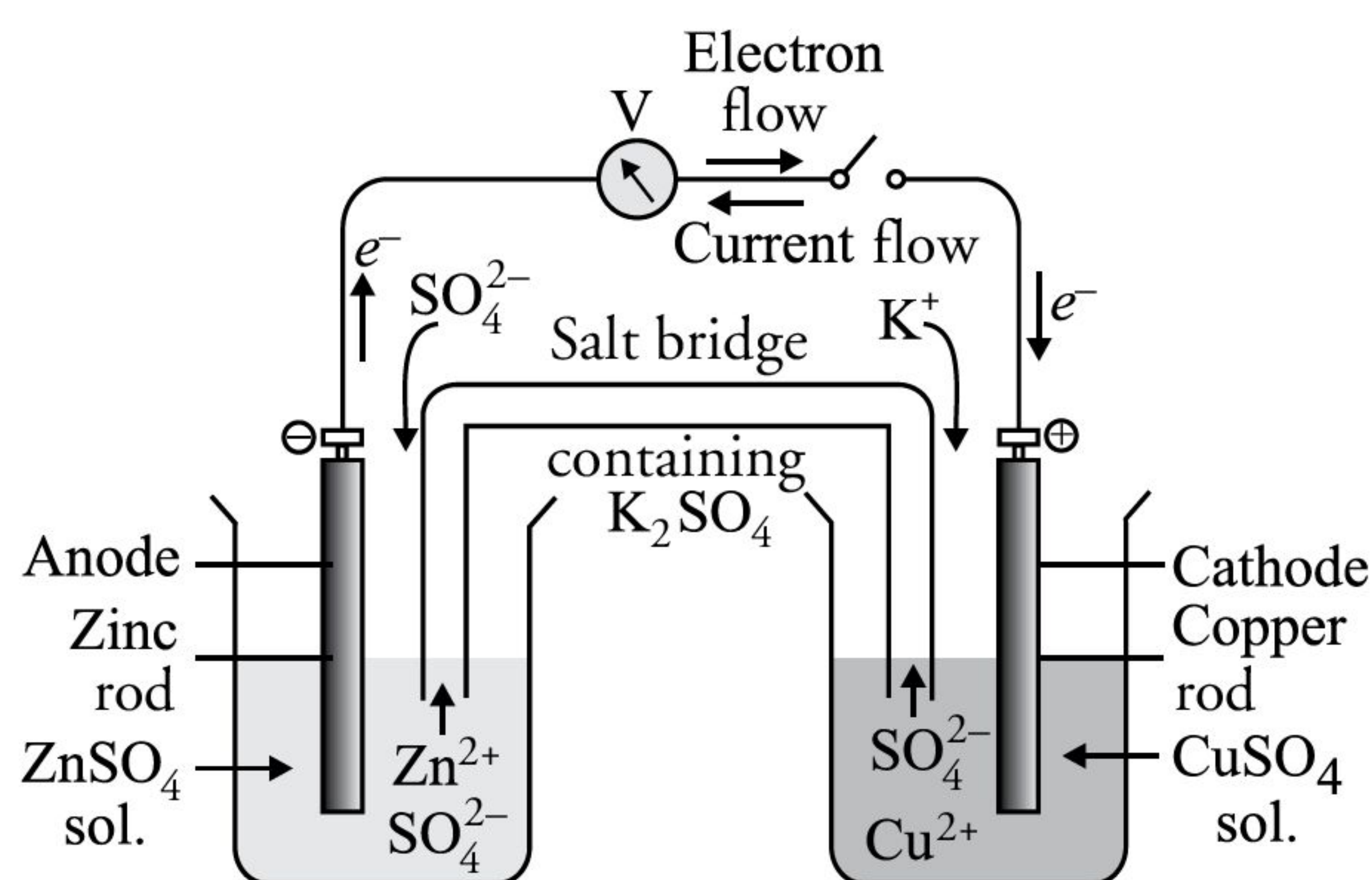
Redox Couple and Salt Bridge

Redox couple : It is defined as having together the oxidised and reduced forms of a substance taking part in an oxidation or reduction half-reaction. For example, in Daniell cell, it is represented as Zn^{2+}/Zn and Cu^{2+}/Cu *i.e.*, a metal dipped in the solution of its own ions.



Important Generalisation

- Oxidation occurs at the anode while reduction occurs at the cathode.
- Electrons flow from anode to cathode in the external circuit while current flows from cathode to anode.
- Chemical energy of the redox reaction occurring in the galvanic cell is converted into electrical energy.
- **Salt bridge** : It completes the circuit by providing an electric contact between two solutions without allowing them to mix with each other and used to maintain electrical neutrality.



Set-up for Daniell cell

Electrode Potential

The potential difference set up at the interface of the metal and its own ions in the solution is called the electrode potential. In general, it is the tendency of an electrode to gain or lose electrons.

Standard electrode potential

If the concentration of each species taking part in the electrode reaction is unity and further the reaction is carried out at 298 K, then the potential of each electrode is called standard electrode potential, E° .

Standard electrode potential of hydrogen is taken as 0.00 volts by convention.

Significance of E° value

The electrode reaction considered for the electrode potential is reduction reaction. Therefore, value and sign of standard electrode potential is a measure of the tendency of active species in the electrode reaction to remain in oxidised/reduced form.

A negative E° means that the redox couple is a stronger reducing agent than the H^+/H_2 couple.

A positive E° means that the redox couple is a weaker reducing agent than the H^+/H_2 couple.

Standard reduction potentials at 298 K

(Electrochemical series)

Reduction half-reaction	Standard reduction potential E° (in volts)
$Li^+ + e^- \rightarrow Li$	- 3.05
$K^+ + e^- \rightarrow K$	- 2.93
$Ca^{2+} + 2e^- \rightarrow Ca$	- 2.87
$Na^+ + e^- \rightarrow Na$	- 2.71
$Mg^{2+} + 2e^- \rightarrow Mg$	- 2.36
$Al^{3+} + 3e^- \rightarrow Al$	- 1.66
$2H_2O(l) + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$	- 0.83
$Zn^{2+} + 2e^- \rightarrow Zn$	- 0.76
$Cr^{3+} + 3e^- \rightarrow Cr$	- 0.74
$Fe^{2+} + 2e^- \rightarrow Fe$	- 0.44
$Cd^{2+} + 2e^- \rightarrow Cd$	- 0.40
$Co^{2+} + 2e^- \rightarrow Co$	- 0.28
$Ni^{2+} + 2e^- \rightarrow Ni$	- 0.25
$Sn^{2+} + 2e^- \rightarrow Sn$	- 0.14
$Pb^{2+} + 2e^- \rightarrow Pb$	- 0.13
$2H^+ + 2e^- \rightarrow H_2$	0.00
$Cu^{2+} + 2e^- \rightarrow Cu$	+ 0.34
$Cu^+ + e^- \rightarrow Cu$	+ 0.52
$I_2 + 2e^- \rightarrow 2I^-$	+ 0.54
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+ 0.77
$Ag^+ + e^- \rightarrow Ag$	+ 0.80
$Br_2 + 2e^- \rightarrow 2Br^-$	+ 1.09
$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O$	+ 1.23
$Cl_2 + 2e^- \rightarrow 2Cl^-$	+ 1.36
$Au^{3+} + 3e^- \rightarrow Au$	+ 1.40
$Co^{3+} + e^- \rightarrow Co^{2+}$	+ 1.81
$F_2 + 2e^- \rightarrow 2F^-$	+ 2.87

Increasing strength of oxidising agent

Increasing strength of reducing agent

HYDROGEN

Hydrogen is the first element in the periodic table and is the lightest known element. It was discovered by Henry Cavendish in 1766. It exists as a diatomic molecule, H_2 .

ANOMALOUS POSITION OF HYDROGEN

The atomic number of hydrogen is 1 and it has an electronic configuration of $1s^1$. It resembles with both alkali metals and halogens in its properties, so its position in the periodic table is anomalous.

Resemblance with Alkali Metals

Property	Hydrogen	Alkali metals
Electronic configuration	$1s^1$	ns^1
Electropositive character	$H \rightarrow H^+ + e^-$	$Na \rightarrow Na^+ + e^-$
Valency and oxidation state	H^+Cl^- (+1 oxidation state) (binary compound formation)	Na^+Cl^- (+1 oxidation state)
Combination with electronegative elements	H_2S, H_2O , etc.	Na_2S, Na_2O , etc.
Liberation at cathode	$2HCl_{(aq)} \xrightarrow{\text{Electrolysis}} H_{2(g)} + Cl_{2(g)}$ At cathode	$2NaCl_{(l)} \xrightarrow{\text{Electrolysis}} 2Na_{(l)} + Cl_{2(g)}$ At cathode
Reducing agent	$CuO + H_2 \rightarrow Cu + H_2O$	$CuO + 2Na \rightarrow Cu + Na_2O$

Differences between hydrogen and alkali metals

- Ionization energy of hydrogen is very high as compared to alkali metals. For example, IE of $H = 1312 \text{ kJ mol}^{-1}$, IE of $Li = 520 \text{ kJ mol}^{-1}$.
- Alkali metals are metals while hydrogen is a non-metal.
- Hydrogen is diatomic (H_2) whereas alkali metals are monoatomic.
- The compounds of hydrogen are predominantly covalent while those of alkali metals are ionic, e.g.,

HCl is covalent while $NaCl$ is ionic.

- The oxides of alkali metals are basic while hydrogen oxide (H_2O) is neutral.

Resemblance with Halogens

Property	Hydrogen	Halogens
Electronic configuration	$H : 1s^1$ (one e^- less than nearest noble gas configuration)	$ns^2 np^5$ (one e^- less than nearest noble gas configuration)
Ionization energy	$H : 1312 \text{ kJ mol}^{-1}$	$Cl : 1255 \text{ kJ mol}^{-1}$
Electronegative character	$H + e^- \rightarrow H^-$	$F + e^- \rightarrow F^-$
Oxidation state	Na^+H^- (oxidation state $= -1$)	Na^+Cl^- (oxidation state $= -1$)
Diatomic nature	H_2	Br_2, I_2
Liberation at anode	$2NaH_{(l)} \xrightarrow{\text{Electrolysis}} 2Na_{(l)} + H_{2(g)} \uparrow$ (At anode)	$2NaCl_{(l)} \xrightarrow{\text{Electrolysis}} 2Na_{(l)} + Cl_{2(g)} \uparrow$ At anode
Non-metallic nature	Non-metallic	Non-metallic
Nature of compounds	CH_4, NH_3, PH_3 , etc. (covalent compounds with non-metals)	CCl_4, NCl_3, PCl_3 , etc. (covalent compounds with non-metals)

Differences between hydrogen and halogens

- Hydrogen is less electronegative than halogens.
- Hydrogen atoms do not possess any lone pairs whereas there are three lone pairs on each halogen atom in its molecule.
- The oxides of halogens are acidic while hydrogen oxide (H_2O) is neutral.



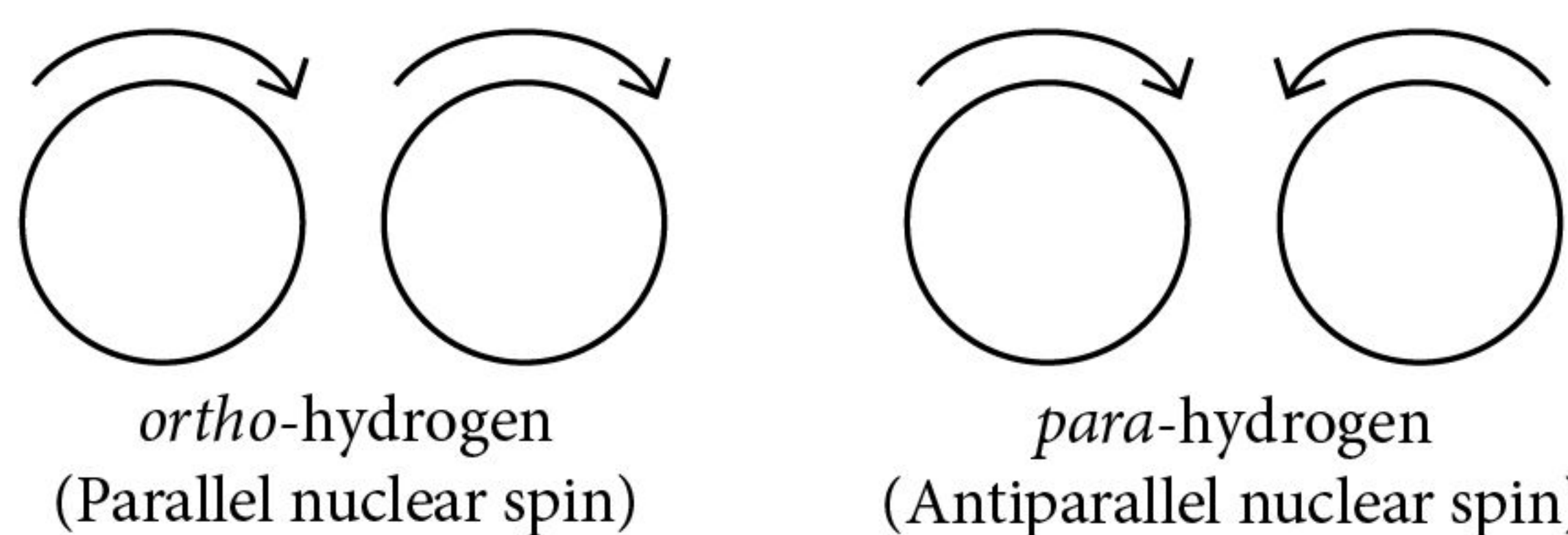
ISOTOPES OF HYDROGEN

Hydrogen occurs in three isotopic forms.

Isotope	Symbol	Atomic number	Mass number	No. of neutrons	Relative abundance (%)	Nature
Protium or Hydrogen	^1_1H or H	1	1	0	99.985	Non-radioactive
Deuterium	^2_1H or D	1	2	1	0.0156	Non-radioactive
Tritium	^3_1H or T	1	3	2	10^{-15}	Radioactive

Ortho and Para-Hydrogen

In *ortho*-hydrogen, both the hydrogens have same spin of nuclei whereas in *para*-hydrogen, nuclei have opposite spin. At ordinary atmospheric conditions, there is 75% *ortho* and 25% *para* hydrogen.

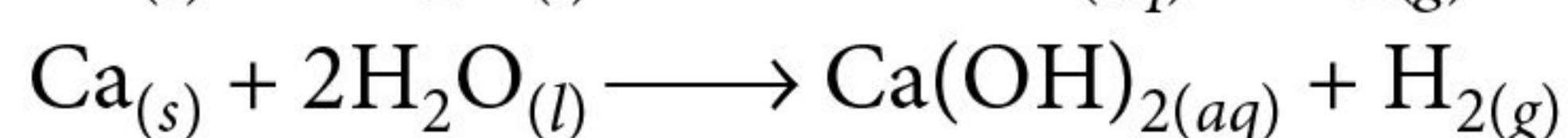
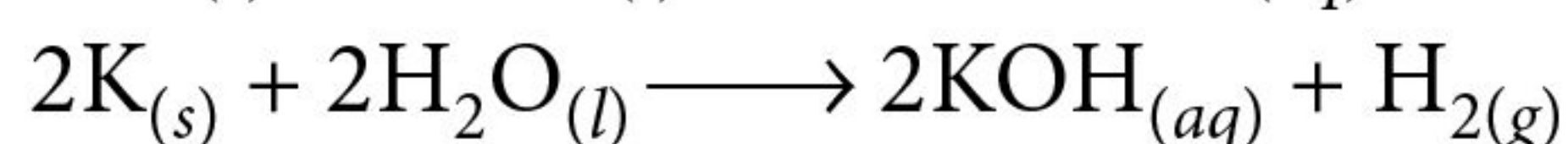
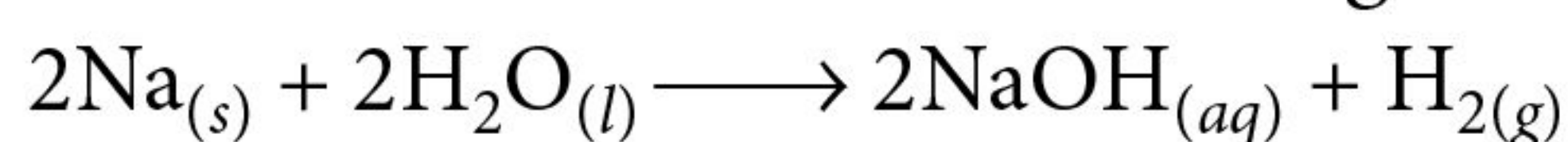


These are known as nuclear spin isomers of hydrogen. The two isomers have 1 and 0 nuclear spin respectively.

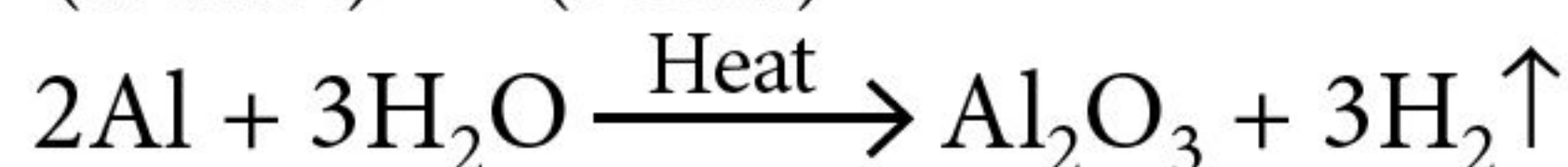
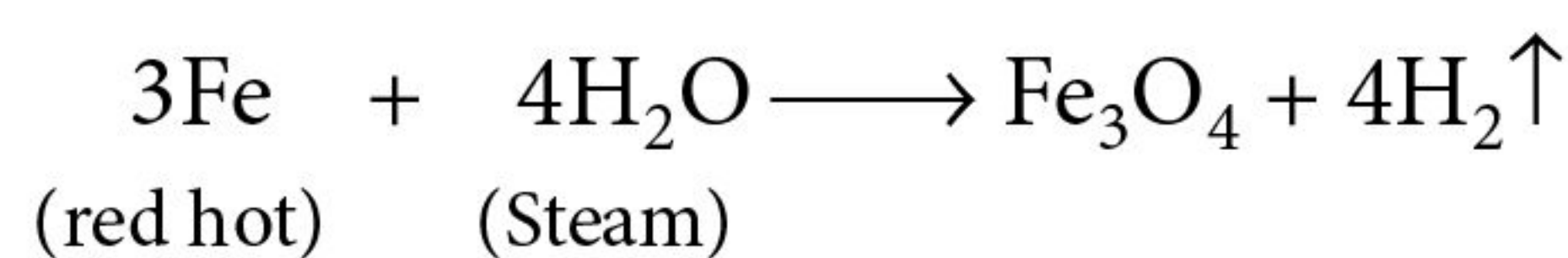
PREPARATION OF HYDROGEN

- **By the action of steam or hot water on active metals.**

Dihydrogen can be prepared by the action of water or dilute mineral acid on metals. *e.g.*,



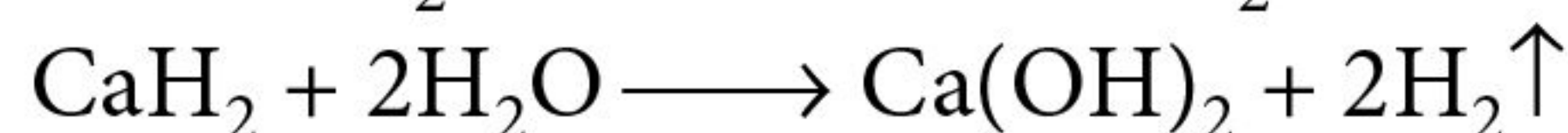
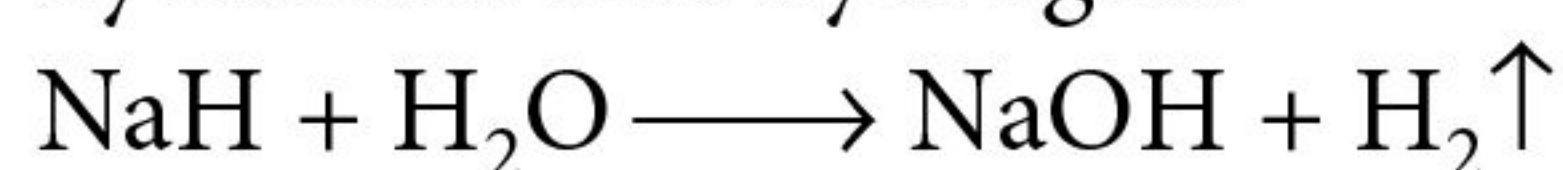
Some metals like Mg, Zn, Al react with hot water to form oxides and $\text{H}_{2(g)}$. Iron (red hot) reacts with steam.



- **Laboratory preparation:** In the laboratory, hydrogen is prepared by the action of zinc granules with dil. HCl or H_2SO_4 . *e.g.*,

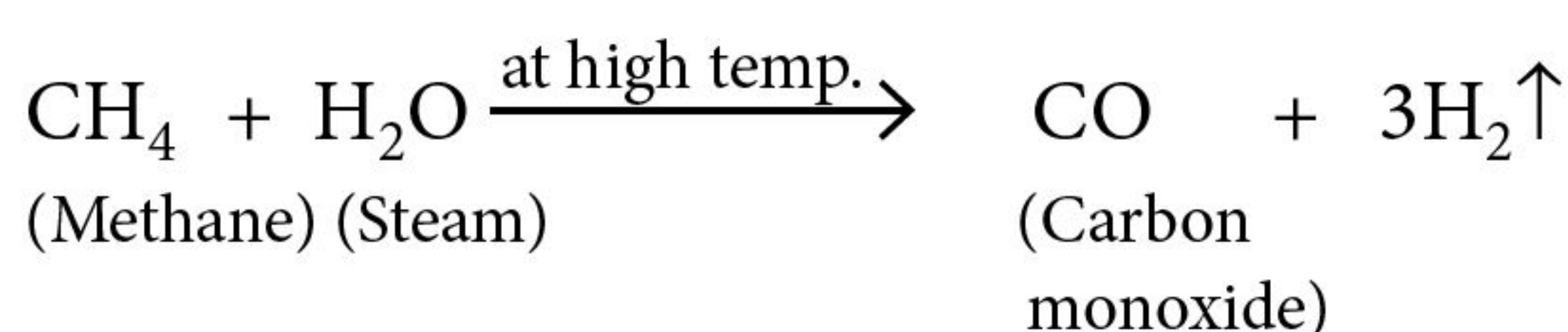


- **By reaction of water with metal hydrides :** Metal hydrides on reaction with water form metal hydroxide and hydrogen.



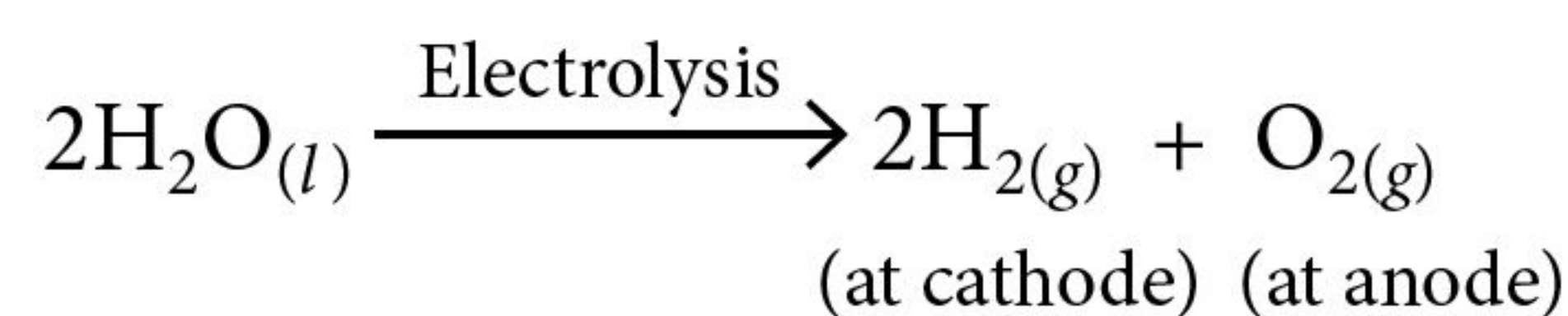
- **By the reaction of methane and steam**

Reaction of steam on hydrocarbons or coke at high temperatures in the presence of catalyst yield hydrogen.

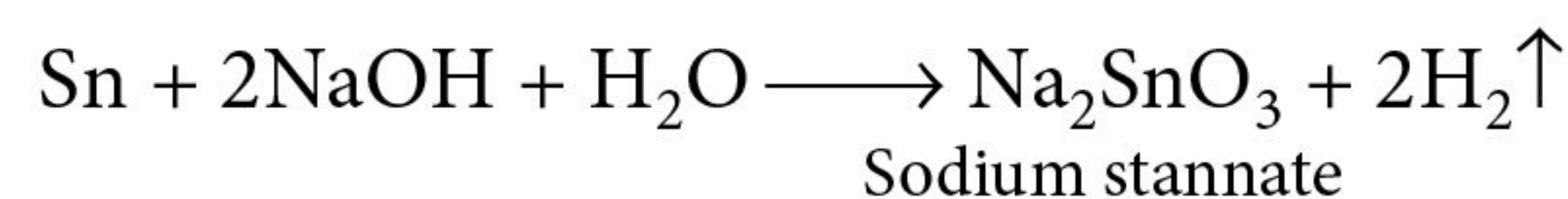
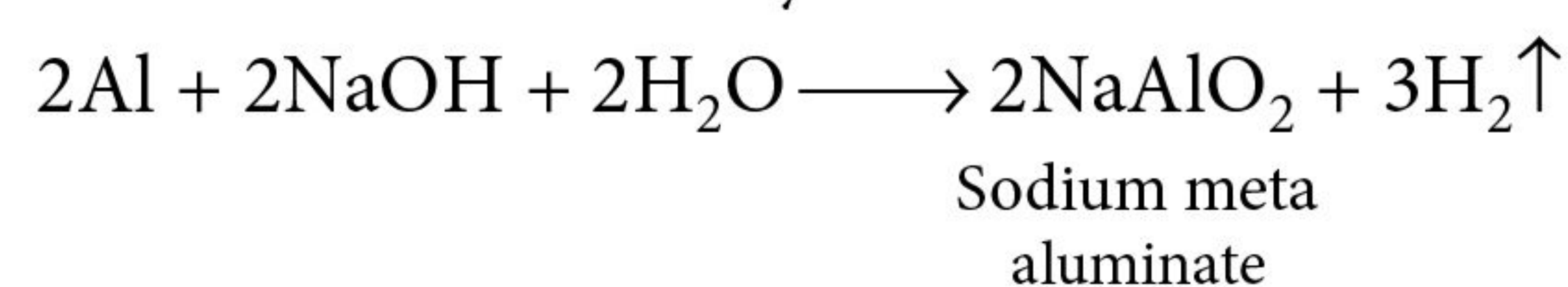
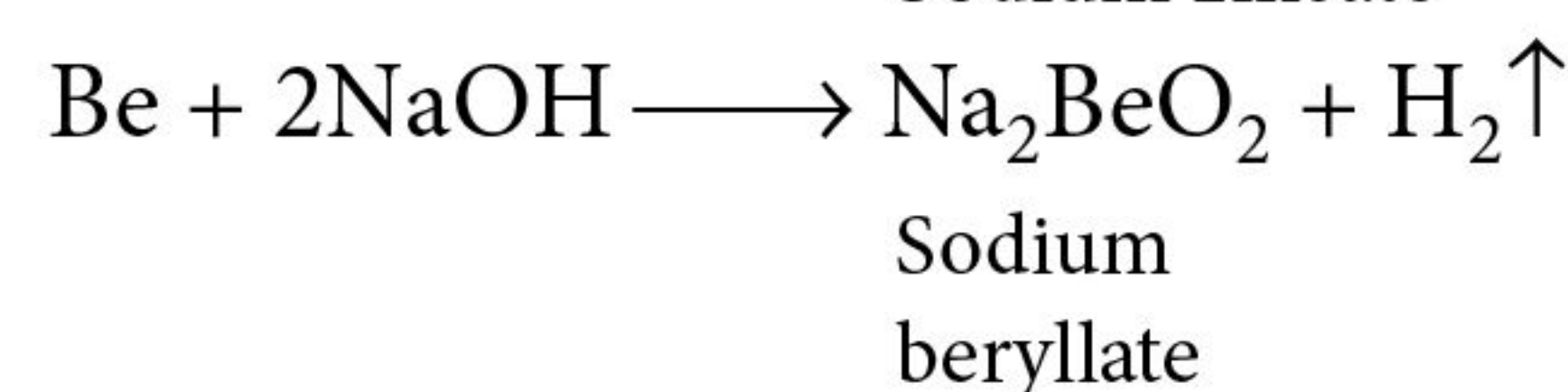
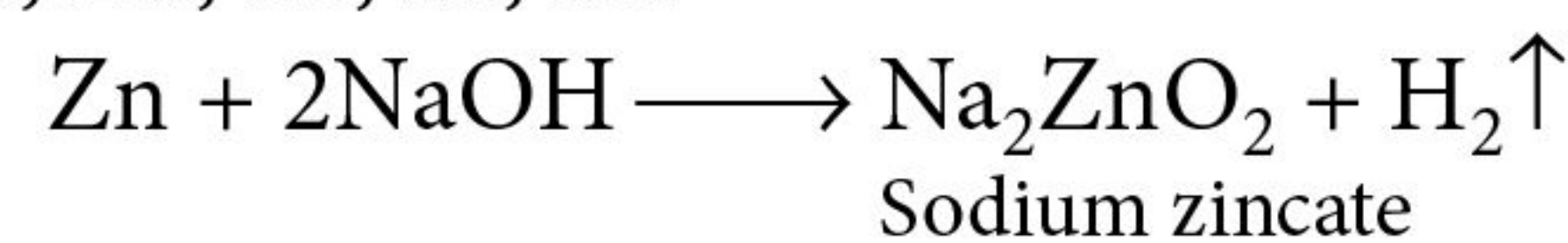


The mixture of CO and H_2 is called 'water gas' or 'syngas'.

- **By electrolysis :** On large scale pure hydrogen is obtained by electrolysis of acidified water.

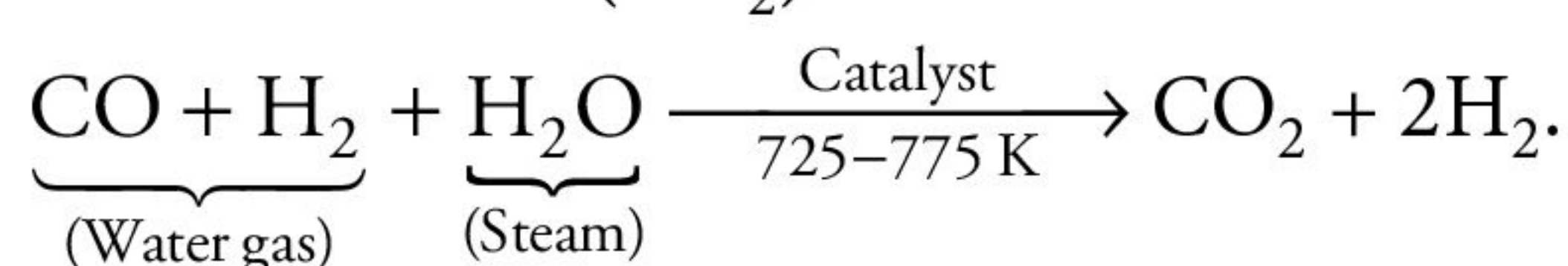


- High purity (>99.95%) dihydrogen is obtained by electrolysis of warm aqueous barium hydroxide solution between nickel electrodes.
- **By the action of metals with alkalis :** Hydrogen can be obtained by reaction of metals with alkalis. *e.g.*, Zn, Be, Al, Sn.



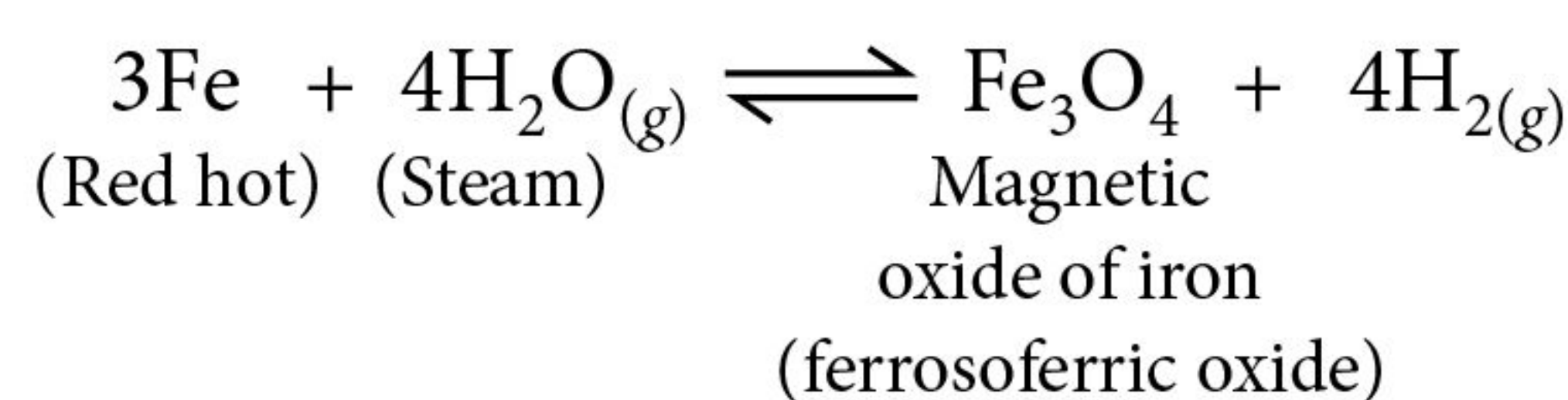
- **Bosch process :** This process is used for the industrial preparation of hydrogen gas. In this process, hydrogen is obtained from water gas (a mixture of CO and H_2).

Water gas along with excess of steam is passed over a catalyst ($\text{Fe}_2\text{O}_3 + \text{Cr}_2\text{O}_3$) at 725-775 K where, CO reacts with steam to form hydrogen (H_2) and carbon dioxide (CO_2).



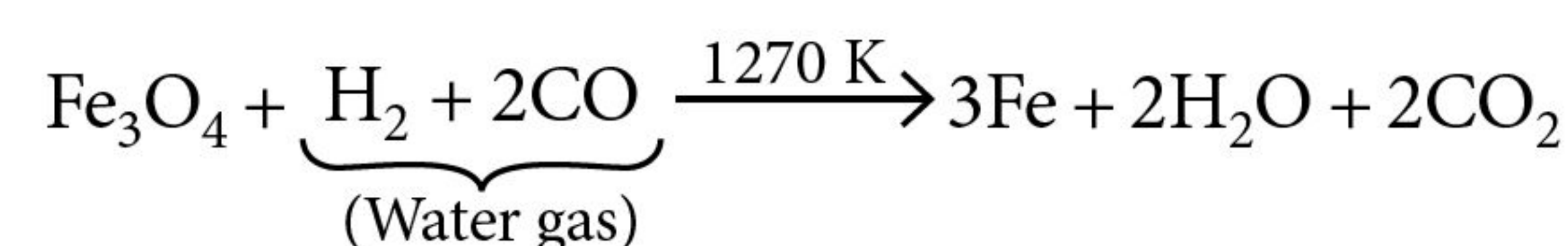
- **Lane's process :** In this process, red hot iron reacts with steam. Iron gets oxidised to Fe_3O_4 and reduces water to $\text{H}_{2(g)}$.

(a) Oxidation stage



(b) Reducing stage

When whole of Fe_3O_4 is oxidized, the supply of steam is cut off and a stream of water gas ($\text{CO} + \text{H}_2$) is passed so as to cause reduction of Fe_3O_4 back to iron.



The oxidation and reduction processes are alternately carried out using two or more furnaces.

- **As a by-product :** Dihydrogen can be obtained as a by-product in the manufacturing of caustic soda by electrolysis of saturated solution of brine (NaCl).

PROPERTIES OF HYDROGEN

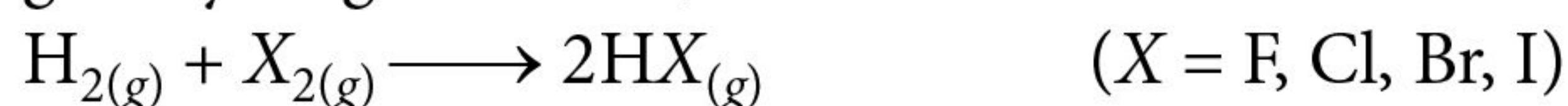
Physical Properties

- It is colourless, odourless and tasteless gas.
- It is diatomic with $\gamma = \frac{C_p}{C_v} = 1.40$.
- It is highly combustible.
- It is neutral towards litmus.
- It is lighter than air and insoluble in water.

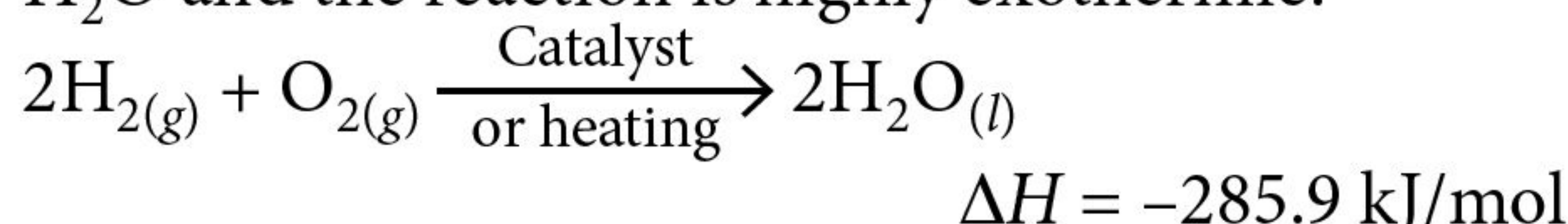
Chemical Properties

- It is less reactive at room temperature because of high bond dissociation energy (436 kJ mol^{-1}) due to smaller bond length.

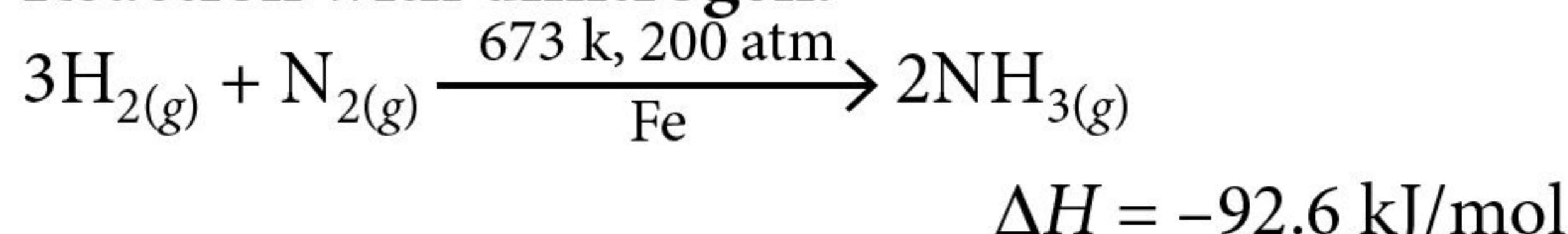
- **Reaction with halogens:** It reacts with halogens to give hydrogen halides, HX



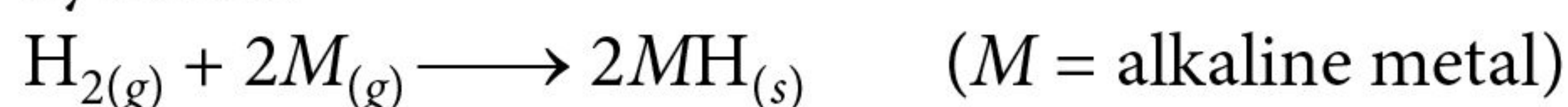
- **Reaction with dioxygen:** It reacts with O_2 to form H_2O and the reaction is highly exothermic.



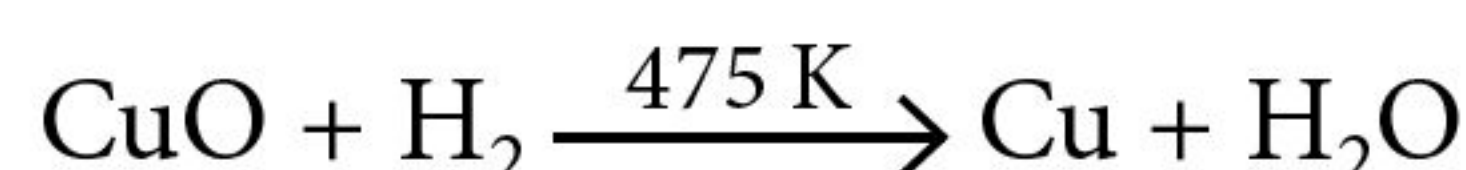
- **Reaction with dinitrogen:**



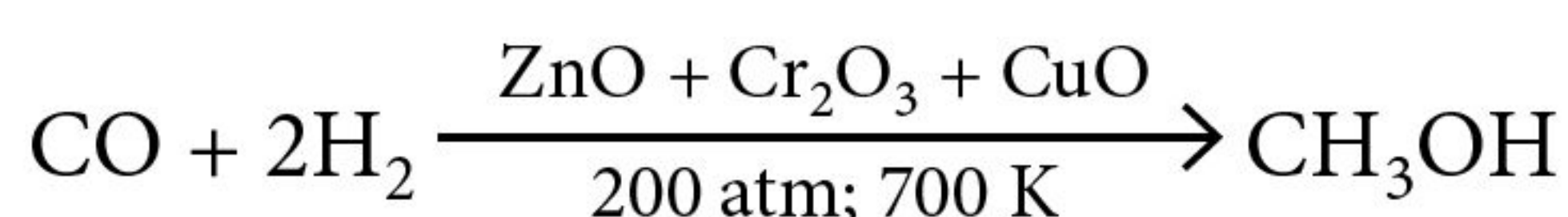
- **Reaction with metals:** With metals it form hydrides.



- **Reducing property :** Dihydrogen is a good reducing agent. It reduces various metal oxides at high temperature. *e.g.*,



- **Reaction with carbon monoxide:** It is used for manufacture of methanol (CH_3OH) which is used as an industrial solvent.



- **Hydrogenation of oils :** Vegetable oils are polyunsaturated (contain $\text{C}=\text{C}$) compounds. When hydrogen, under pressure, is passed through oils at about 450 K in presence of finely divided nickel then the oil changes to solid fat.



HYDRIDES

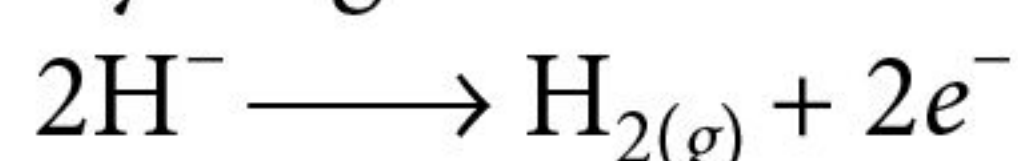
Hydrides are the binary compounds of the elements with hydrogen. These are classified into following types.

- **Ionic or salt-like (IA, IIA) or saline hydrides :** These are formed by electropositive metals. They are held together by ionic or electrovalent bonds. *e.g.*, NaH, KH, CaH_2 etc. Alkali metals and alkaline earth metals form such hydrides when metal is heated in the presence of hydrogen at 600-1000 K.
- **Covalent (or molecular) hydrides :** These are hydrides formed by non-metals or less electropositive elements and hydrogen. The atoms are held together by covalent bonds. *e.g.*, CH_4 , H_2O , H_2S , NH_3 , BeH_2 , MgH_2 etc. The *p*-block elements form such hydrides by direct combination of the element with hydrogen under appropriate conditions. Molecular hydrides are further classified as (i) electron-deficient (group 13), (ii) electron-precise (group 14) and (iii) electron-rich (group 15-17) hydrides.
- **Interstitial (or metallic) hydrides :** They are obtained by heating many *d*-block and *f*-block elements with hydrogen. Interstitial hydrides are those in which the hydrogen atoms occupy holes (interstices) in the metal structure. Transition metals (*d*-block elements) of group 3, 4, 5 and *f*-block elements form metallic hydrides. In group 6, only chromium forms hydride like CrH. Elements of group 7, 8, 9 do not form hydrides. This region of periodic table is referred to as hydride gap.

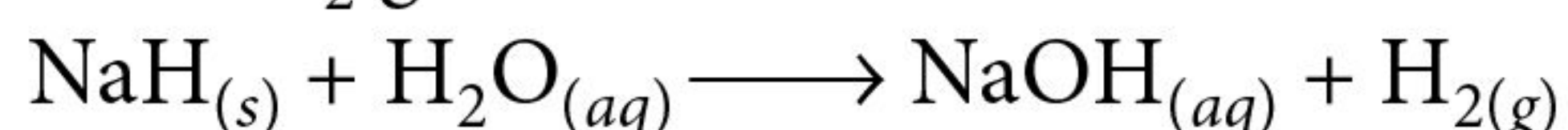
Properties of Hydrides

- **Saline or ionic hydrides :** Ionic hydrides are crystalline solids, behave as salt due to the presence of ions. They have high M.pt. and B.pt. and conduct electricity in molten state.
 - Binary hydrides of alkali metals have rock salt (NaCl) type structure.
 - The thermal stability of alkali metal hydrides decreases from LiH to CsH as $\text{LiH} > \text{NaH} > \text{KH} > \text{RbH} > \text{CsH}$. It is due to increase in atomic size of alkali metals. The order of stability in the alkaline earth metal hydrides is $\text{CaH}_2 > \text{SrH}_2 > \text{BaH}_2$.

- Electrolysis of molten saline hydrides produce hydrogen gas at anode which confirms the existence of H^- and electronegative nature of hydrogen.



- Saline hydrides react violently with water to form H_2 gas.



- **Covalent or Molecular hydrides** : p -block elements form molecular hydrides. *e.g.*, CH_4 , NH_3 , H_2O , HF , HI , HBr , PH_3 , NH_3 .

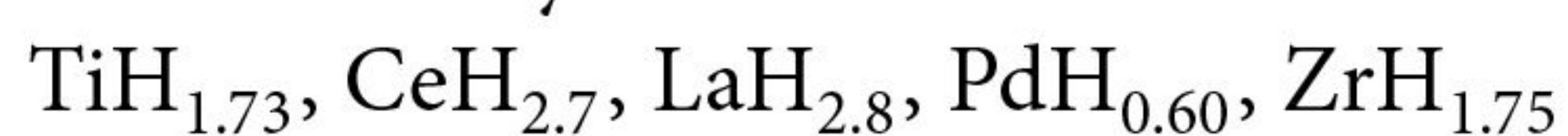
These hydrides can be further classified as

- **Electron deficient hydrides** : Molecular hydrides (*i.e.*, hydrides of group 13) in which central atom does not have complete octet are called electron deficient. *e.g.*, BeH_2 , BH_3 (it exists as a polymeric hydride, B_2H_6 called diborane).
- **Electron precise hydrides** : Those hydrides in which central atom has complete octet are called electron precise hydrides. *e.g.*, hydrides of group 14 such as CH_4 , SiH_4 , GeH_4 . They have tetrahedral structure. Their stability decreases down the group due to increase in bond length.
- **Electron rich hydrides** : Those hydrides in which the central metal atom have lone pair of electrons are called electron rich hydrides. *e.g.*, NH_3 , PH_3 (having one lone pair), H_2O , H_2S (having two lone pairs).

The presence of lone pair on highly electronegative atom like O, F, N in electron rich hydrides results in the formation of hydrogen bond. The formation of hydrogen bond results in high boiling points, high permittivities and aggregation in such compounds.

H_2O , NH_3 and HF are liquids due to strong intermolecular hydrogen bonding.

- **Metallic or interstitial hydrides** : These hydrides are often non-stoichiometric and their composition vary with temperature and pressure. Formulae of some of the hydrides of this class are:



- They are hard, possess magnetic properties and show metallic lustre.
- They conduct electricity.
- The density of such compounds is less than that of the metal itself and their properties are not much different from their respective metals.

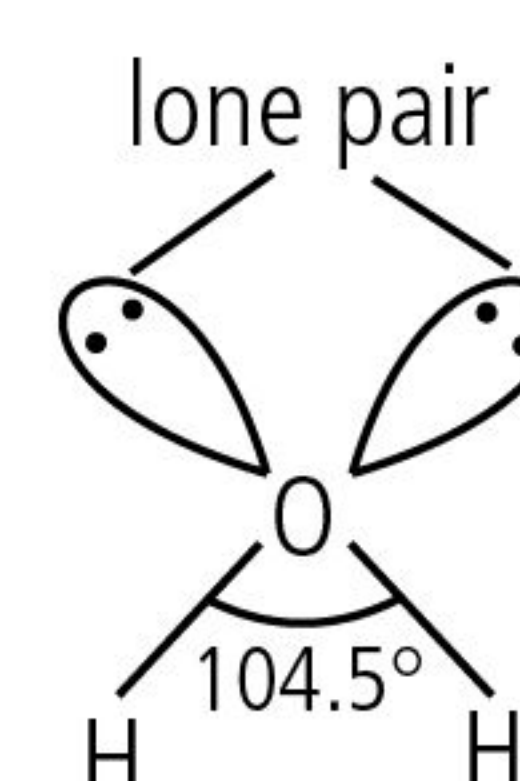
- These compounds are used as industrial reducing agents.

WATER

Water is one of the abundantly available substances in nature. It is an essential constituent of all animal and vegetable matter.

Structure of Water Molecule

Oxygen atom in water molecule is sp^3 hybridised, four hybrid orbitals directed towards the corners of a tetrahedron. Two of the hybrid orbitals having one electron each overlap with two hydrogen atoms and form two sigma bonds. Thus, the molecule has a bent structure with a bond angle of 104.5° in gas phase.



Hydrogen Bonding in Water and Ice

Because of the polar nature of water molecule, in liquid and solid phase, the water molecules are held together by intermolecular hydrogen bonds. In this arrangement each oxygen is tetrahedrally surrounded by four hydrogen atoms, two by covalent bonds and two by hydrogen bonds. Experimental studies have shown that liquid water and ice consist of aggregates of varying number of water molecules by hydrogen bonds. The resulting structure of ice is open structure having a number of vacant spaces. Therefore, the density of ice is less than liquid water. When the ice melts, some of the hydrogen bonds are broken and the water molecules go in between the vacant spaces in the structure. As a result, the structure of liquid water is less open than structure of ice. Therefore, the density of water is more than that of ice and ice floats over water.

Properties of Water

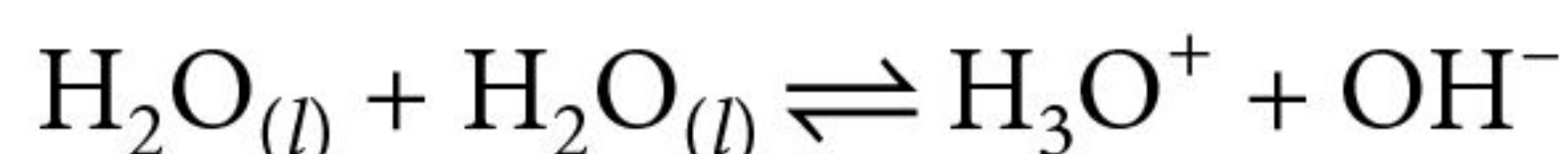
Physical Properties : Pure water is colourless, tasteless and odourless. It freezes at 0°C and boils at 100°C . Its maximum density is 1.00 g/mL at 4°C . It has a high dielectric constant. The polar character of water makes it an excellent solvent for polar and ionic substances.

It is a poor conductor of electricity. It exists in the liquid state not as a single H_2O molecule but as associated molecules through hydrogen bonding. The existence of hydrogen bonding is responsible for high values of

specific heat, latent heat of fusion and latent heat of vaporisation. Net dipole moment of water $\mu = 1.84 \text{ D}$

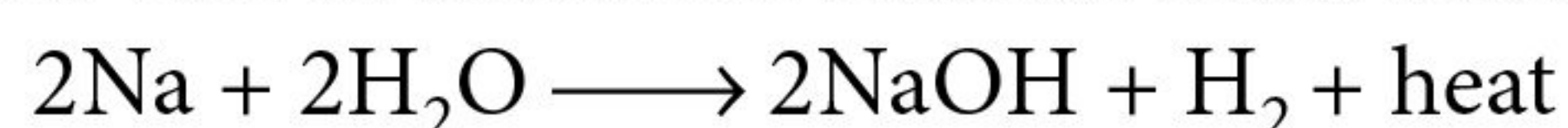
Chemical Properties

- **Self ionisation of water :** pH of the pure water is 7. It is a weak electrolyte and feebly ionises into H^+ and OH^- ions.

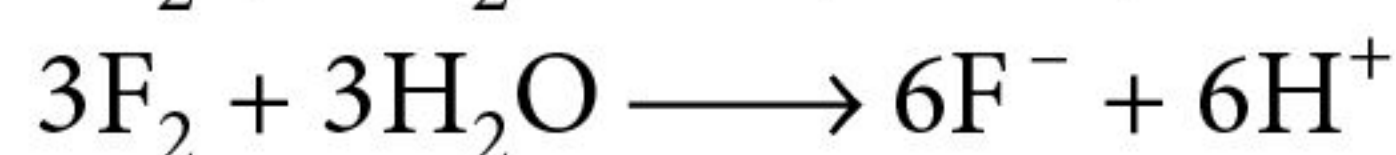
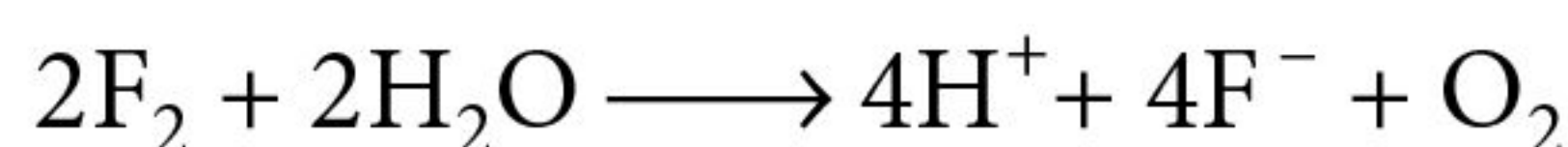


In pure water $[\text{H}_3\text{O}^+] = [\text{OH}^-] = 10^{-7}$ at 25°C .

- **Reaction with metals :** It reacts with active metals and evolves hydrogen. The reaction is exothermic in the case of alkali and alkaline earth metals.



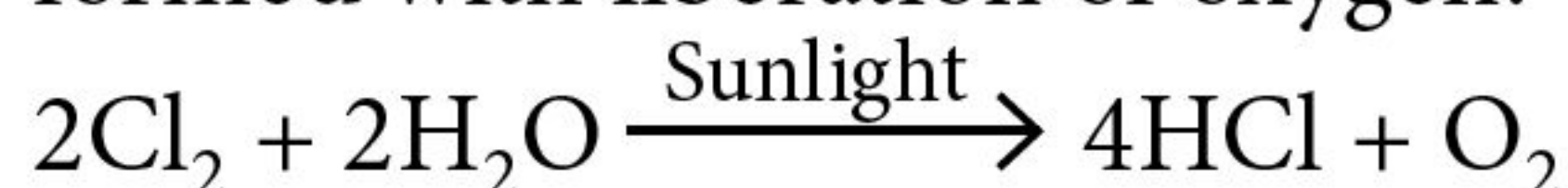
- **Reaction with non-metals :** Fluorine decomposes cold water.



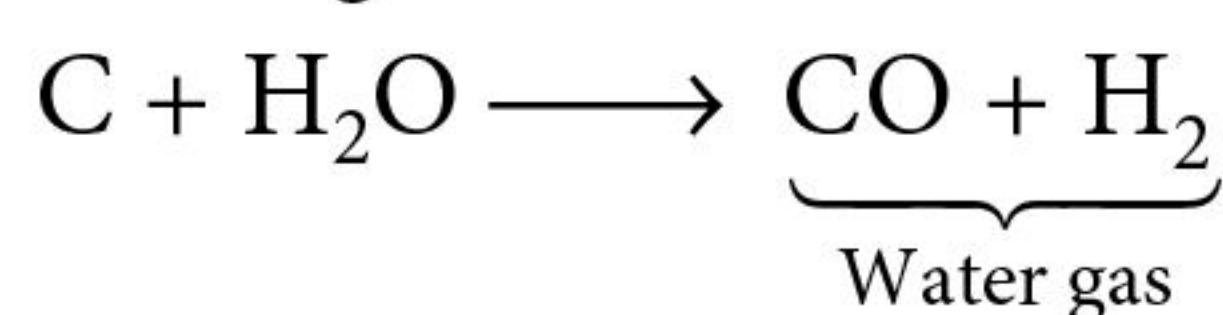
Chlorine decomposes cold water forming HCl and HClO .



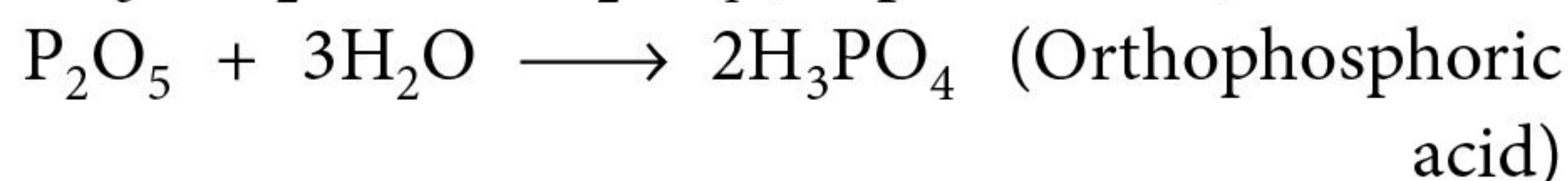
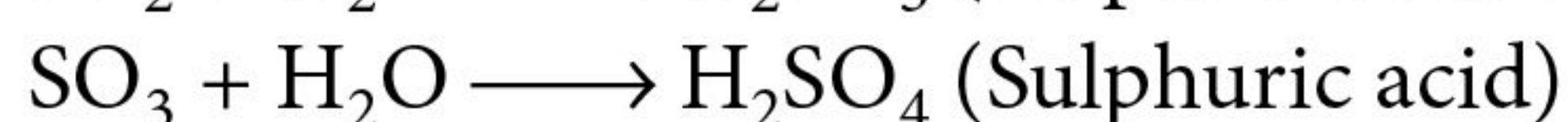
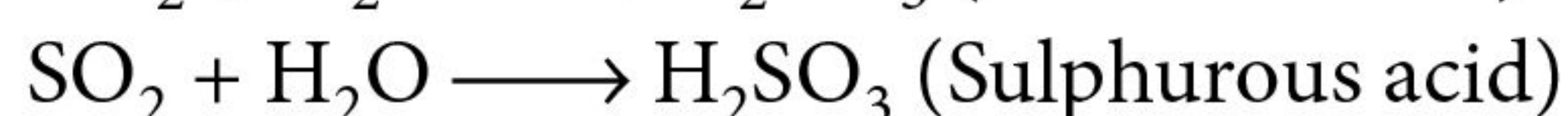
However, in presence of sunlight only HCl is formed with liberation of oxygen.



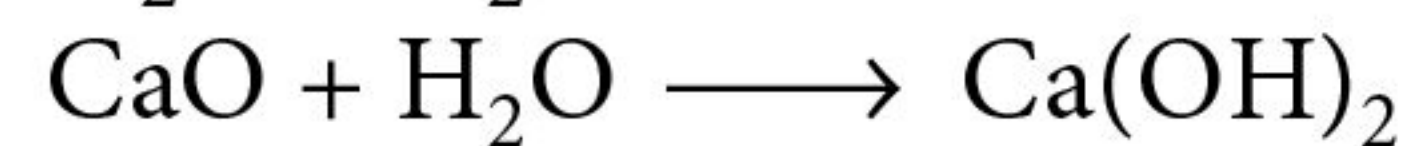
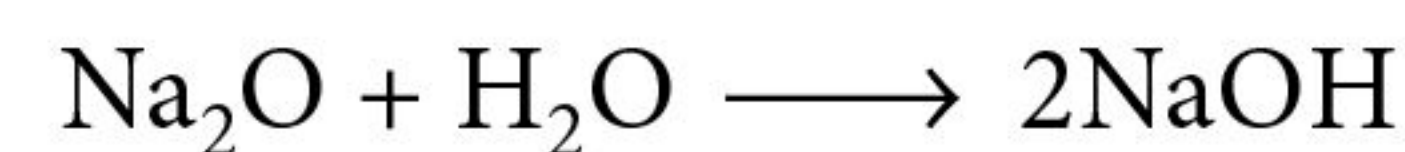
When steam is passed over red hot coke (1000°C), water gas is formed.



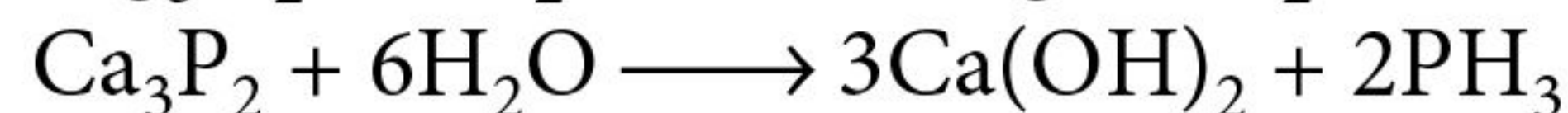
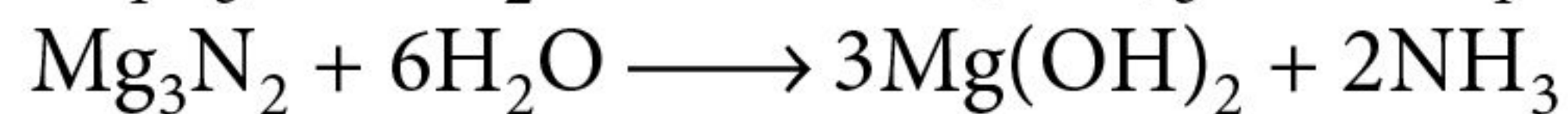
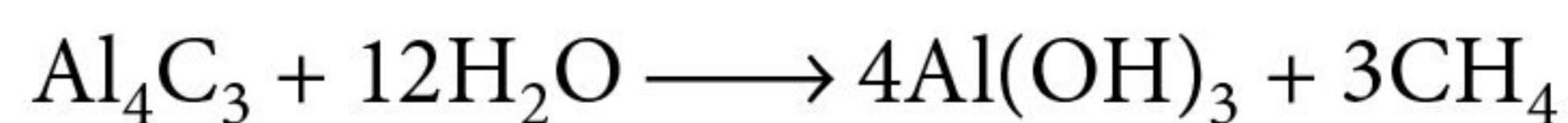
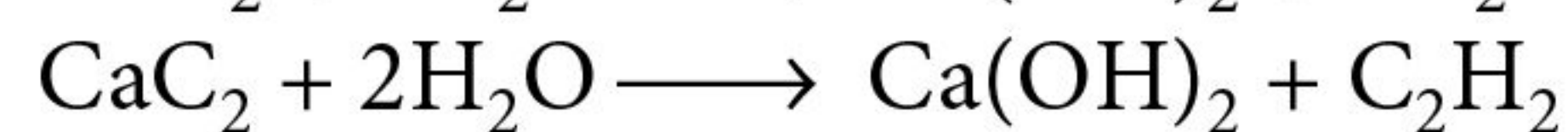
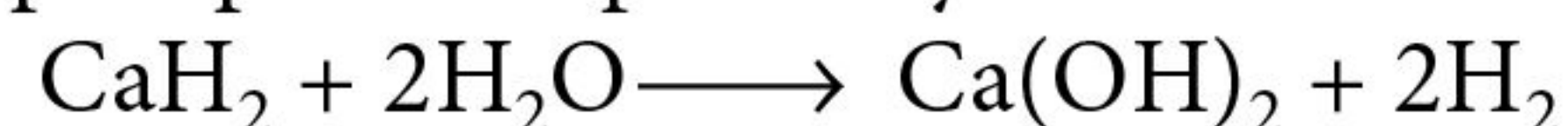
- **Action on non-metallic oxides :** Acidic oxides combine with water to form acids.



- **Action on metallic oxides :** Basic oxides combine with water to form alkalies.

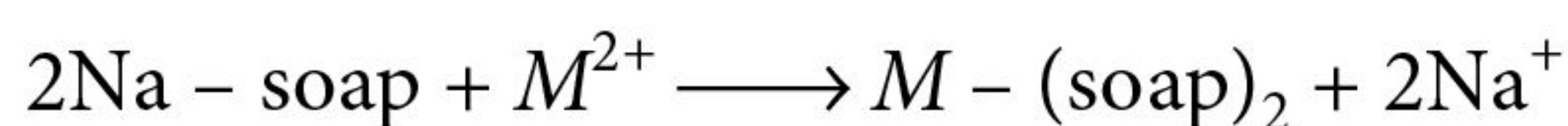


- **Action on hydrides, carbides, nitrides, phosphides :** Water decomposes these compounds with liberation of hydrogen, acetylene (or methane), ammonia, phosphine respectively.



HARD WATER AND SOFT WATER

Water is said to be hard or soft depending on its reaction towards soap. If water gives lather quickly with soap it is called soft water, otherwise it is called hard water. Soap reacts with calcium and magnesium ions present in hard water to form insoluble stearates.



where $\text{M} = (\text{Ca}, \text{Mg})$

The hardness of water is due to soluble salts of Ca and Mg (chlorides, bicarbonates, sulphates etc).

Types of Hardness of Water

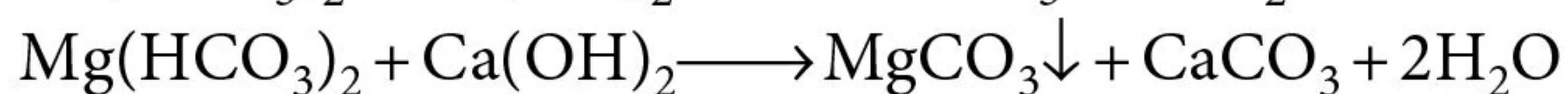
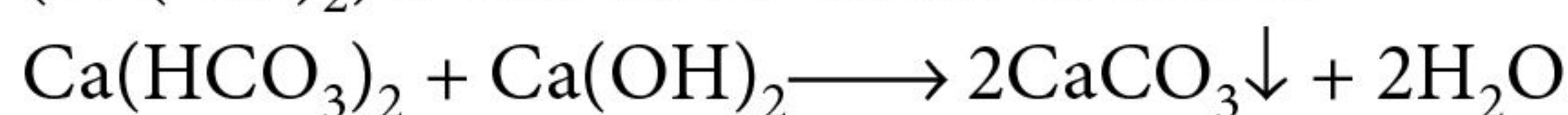
- **Temporary hardness:** Temporary hardness is due to the presence of magnesium and calcium hydrogen carbonates. It can be easily removed by simply boiling and filtering the water.
- **Permanent hardness:** It is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water.

Methods to remove hardness of water

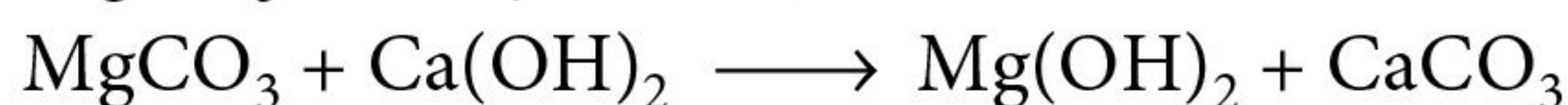
Temporary hardness can be removed by boiling or by adding calculated amount of lime, Ca(OH)_2 .



Clark's method : The process of removing temporary hardness of water using calculated amount of lime (Ca(OH)_2) is known as Clark's method.

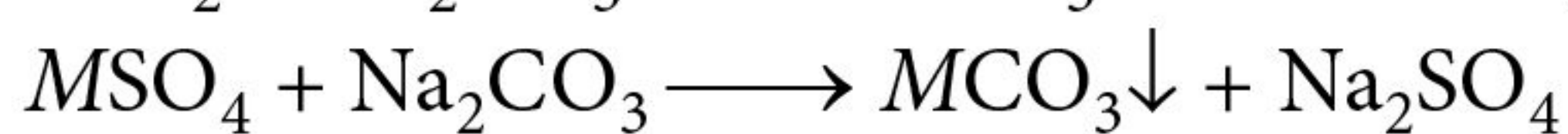


MgCO_3 is fairly soluble, thus



Permanent hardness cannot be removed by boiling or adding lime. This type of hardness is removed by the following important methods.

(a) Treatment with washing soda : Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates.

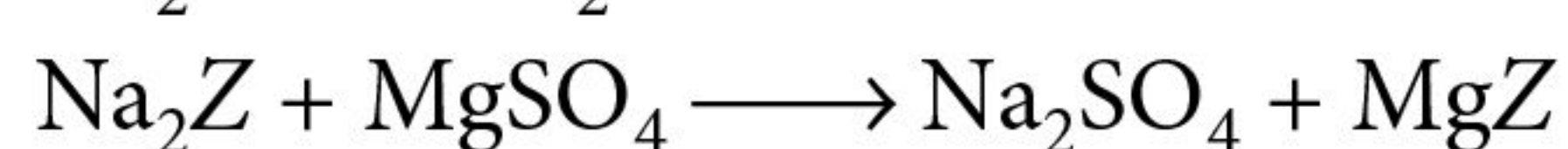
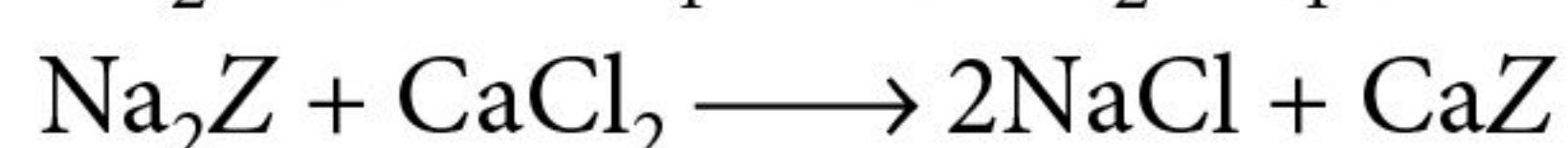
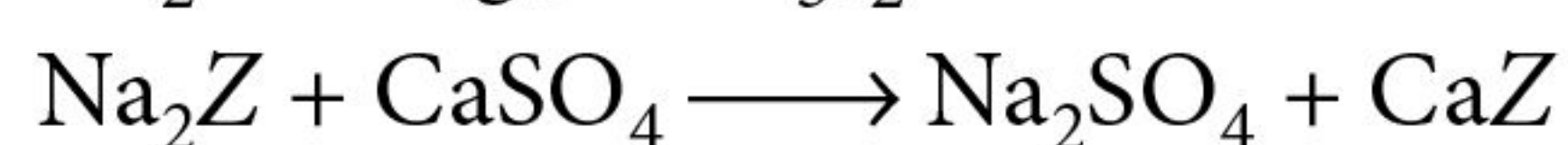
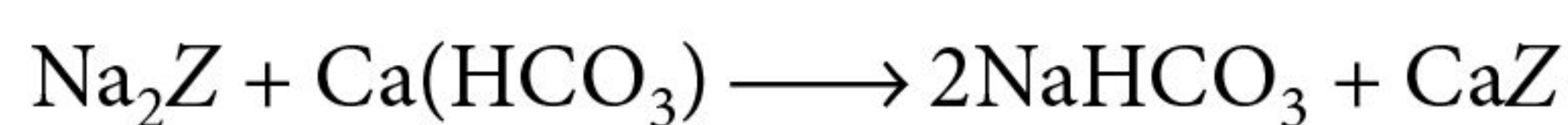


(b) Calgon process : Calgon is the trade name of Graham's salt which is sodium hexametaphosphate ($\text{NaPO}_3)_6$ or $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$. Calgon is used as water softener. When calgon is added to hard water the

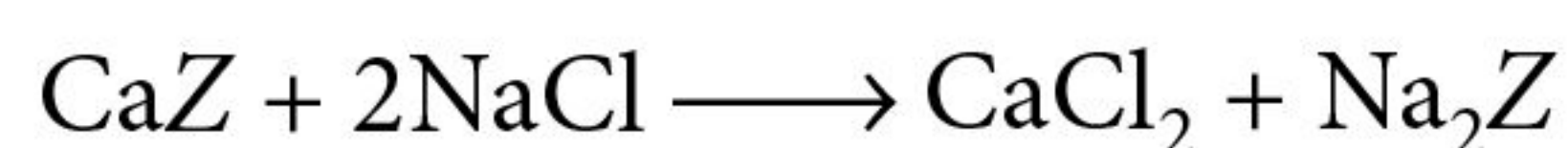
cations causing hardness are removed in the form of complexes.

(c) Ion exchange process :

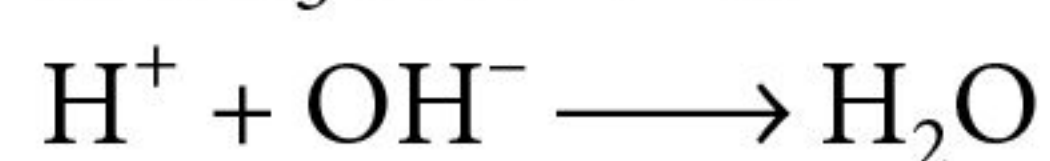
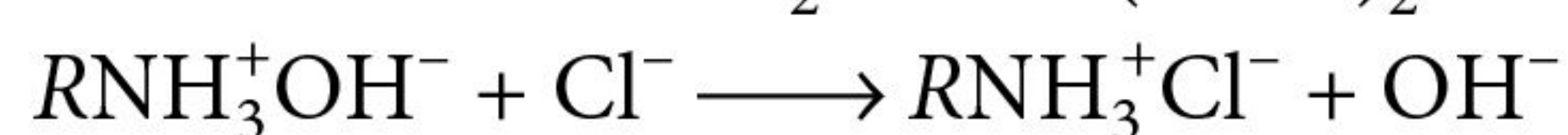
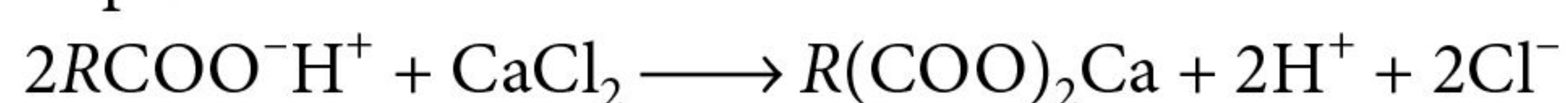
(i) Permutit process (Using zeolite) : Zeolites are naturally occurring aluminosilicates. But artificial zeolite, known as permutit is more common and has a general formula $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot n\text{SiO}_2 \cdot x\text{H}_2\text{O}$ ($n = 5-13$, $x = 3-4$). The zeolite or permutit is insoluble in water. It is placed in a suitable column and hard water containing Ca^{2+} and Mg^{2+} ions is allowed to percolate through it. This process removes both temporary and permanent hardness



The permutit or zeolite is represented as Na_2Z . Water is thus softened as sodium salts (NaCl , Na_2SO_4 etc.) do not cause hardness. After sometime, the whole zeolite gets exhausted. The zeolite may be regenerated by treatment with 10% solution of sodium chloride (NaCl), when sodium salt of zeolite is formed.



(ii) Organic exchangers : A variety of synthetic organic resins have been developed which can exchange cations and anions present in water. A cation exchanger may be defined as high molecular weight cross linked polymer containing sulphonic, carboxylic, phenolic etc., groups as integral part of the resin and equivalent amount of cations. An anion exchange resin is a polymer containing amine or quaternary ammonium groups as integral part of the resin and equivalent amount of anions, such as Cl^- , SO_4^{2-} , OH^- . The cation exchange resin is represented as R^+ and anion exchange resin is denoted as $\text{R}-\text{NH}_2$. Most modern method of water softening is ion exchange method. Ion exchange method can remove all ions from water and the water so obtained is called deionised water or demineralised water. Ion exchangers cannot remove non-electrolyte impurities from water.



Degree of hardness is expressed in ppm (parts per million) of CaCO_3 . Suppose a sample of hard water contains 40 ppm of MgSO_4 , then its hardness can be calculated as,

$$1 \text{ MgSO}_4 = 1 \text{ CaCO}_3 \text{ or } 120 \text{ ppm of MgSO}_4 = 100 \text{ ppm of CaCO}_3$$

Thus 40 ppm of $\text{MgSO}_4 = 100 \times 40/120 = 33.33$ ppm of CaCO_3 .

HEAVY WATER

Deuterium oxide (D_2O) is called heavy water. It was discovered by Harold C. Urey an American chemist in 1932.

Preparation

By fractional distillation of ordinary water : The boiling points of ordinary water (H_2O) and heavy water (D_2O) are 100°C and 101.42°C , respectively. Since the difference in boiling points is very small, the fractional distillation of ordinary water is done in a very long fractionating column (13 metres long) and the process is repeated several times. The lighter fraction (H_2O) is distilled first while the heavier fraction (D_2O) is left behind. The heavier fraction becomes richer in D_2O .

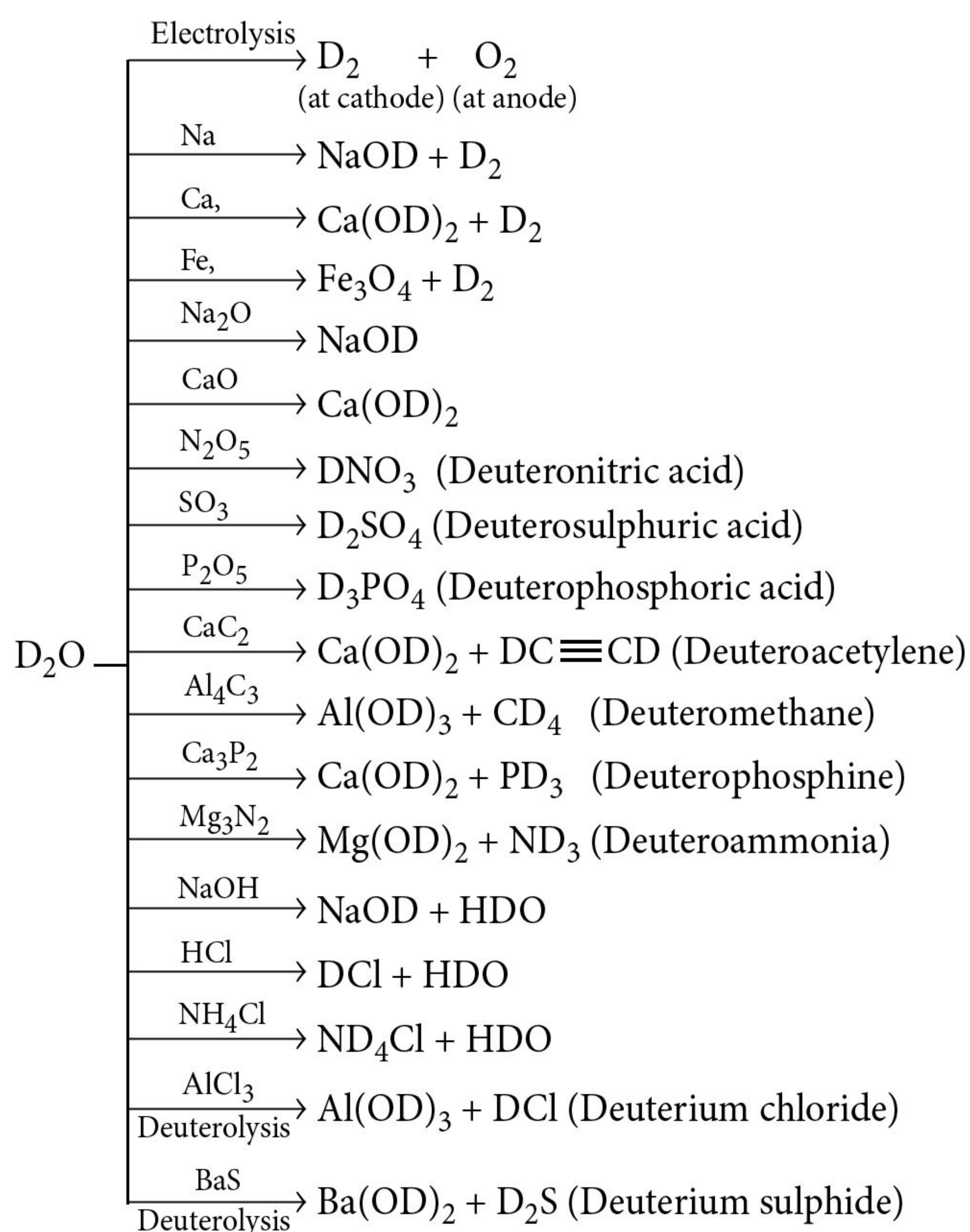
Properties of Heavy Water

- Heavy water is a colourless, odourless and tasteless mobile liquid.
- Nearly all the physical constants are higher than the corresponding values of ordinary water. The comparison of physical constants is tabulated here:

Physical property	H_2O	D_2O
Maximum density (g/mL)	1.00 at 298 K	1.1059 at 298 K
Melting point	0°C or 273 K	3.82°C or 276.82 K
Boiling point	100°C or 373 K	101.42 or 374.2 K
Specific heat	1.00 cal/g K	1.01 cal/g K
Latent heat of fusion	79.7 cal/g	75.5 cal/g
Latent heat of vaporisation	539 cal/g	557 cal/g
Viscosity at 20°C	10.09 millipoise	12.6 millipoise

Surface tension at 20 °C	72.8 dynes/cm	67.8 dynes/cm
Dielectric constant	78.39	78.06
Solubility of NaCl (per lit.)	359 g	305 g
Molecular mass	18.016	20.03
Dissociation constant or ionic product at 25 °C	1.0×10^{-14}	0.3×10^{-14}

Chemical Properties of Heavy Water



Uses

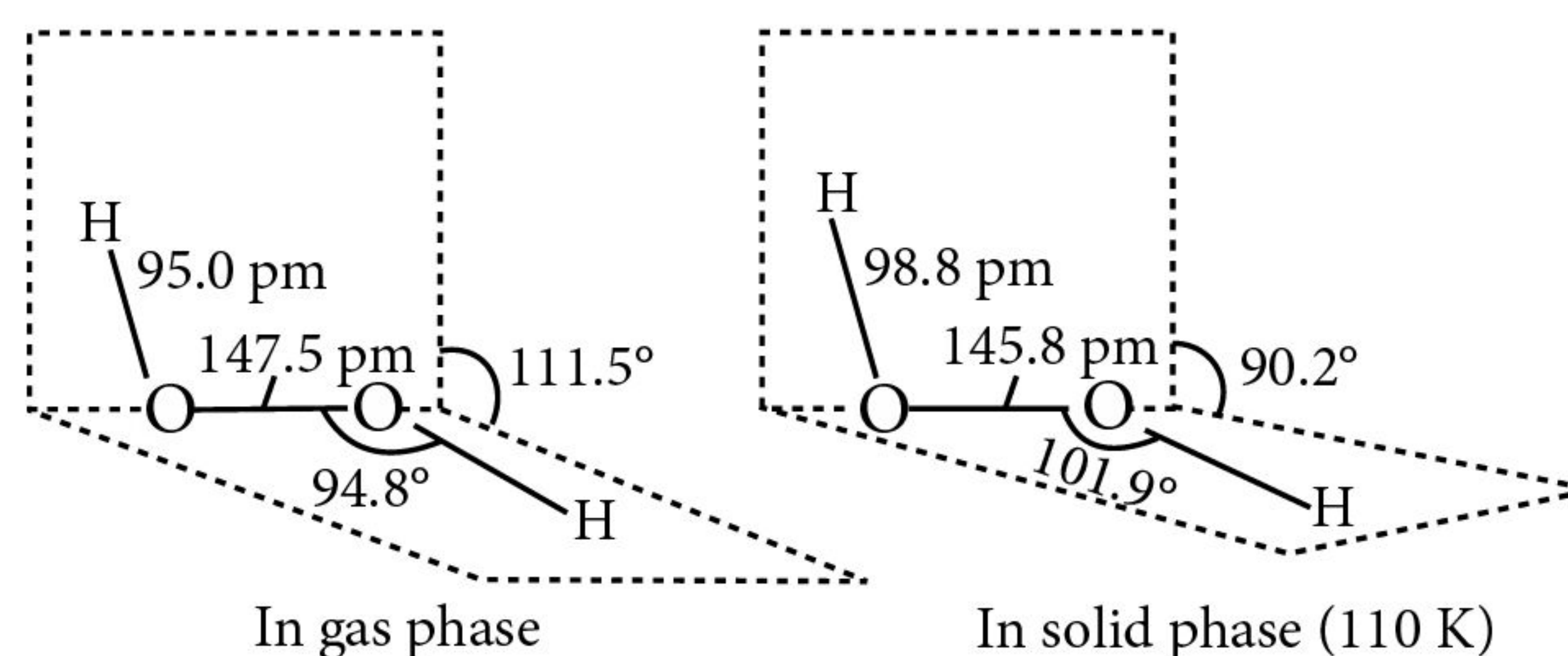
- As moderator in nuclear reactor.
- As a tracer compound to study various reaction mechanisms.
- For the preparation of various deuterium compounds.
- As a germicide and bactericide.

HYDROGEN PEROXIDE

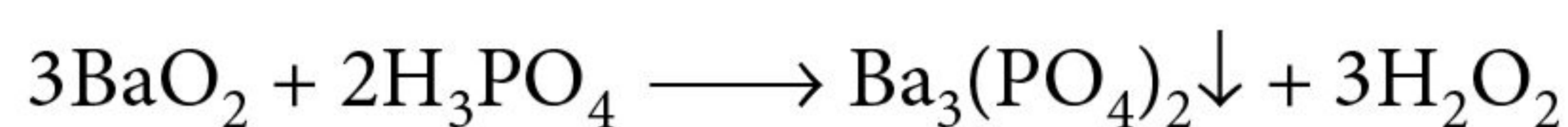
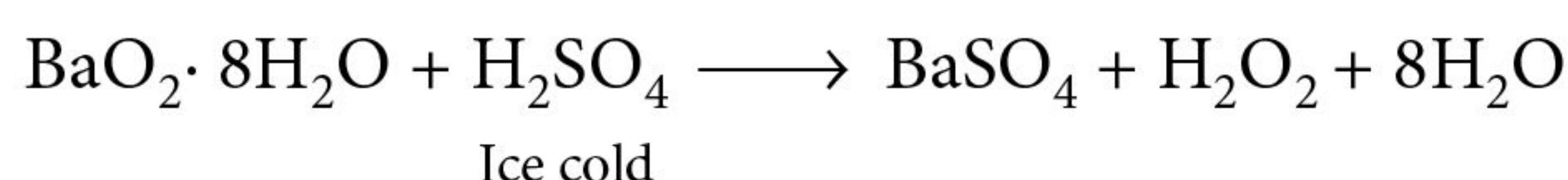
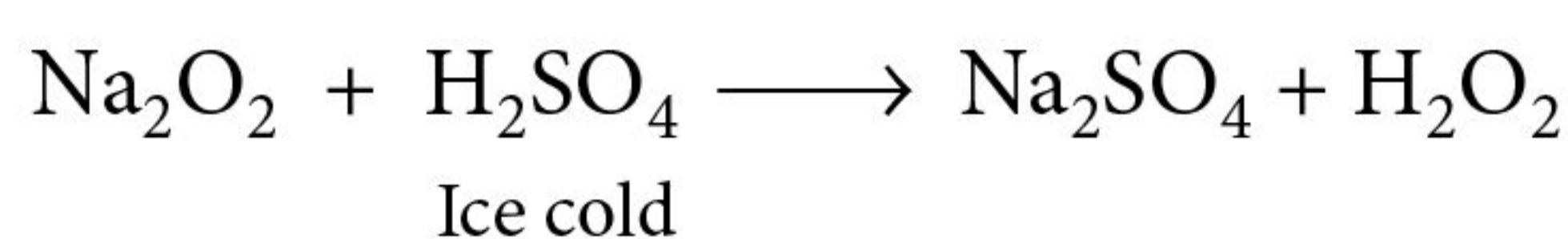
Hydrogen peroxide (H₂O₂) is also known as oxygenated water.

Structure of Hydrogen Peroxide

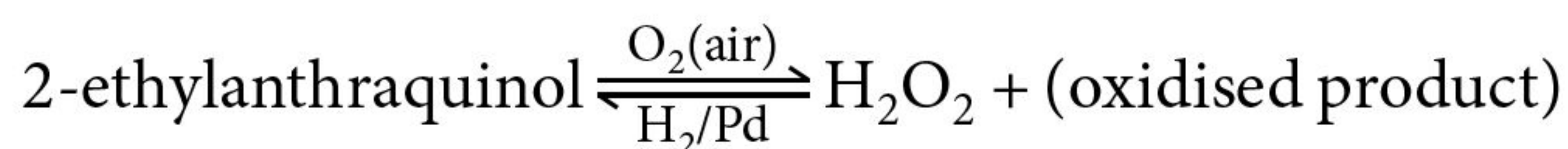
Hydrogen peroxide is a non-planar molecule. It has an open book like structure. In gaseous phase the dihedral (interplanar) angle between two planes is 111.5° but in crystalline state it reduces to 90.2° due to hydrogen bonding.



Preparation



By auto-oxidation of 2-alkylanthraquinols



Physical Properties of Hydrogen Peroxide

- Pure hydrogen peroxide is a pale-blue syrupy liquid with a bitter taste.
- It is soluble both in water and alcohol.
- It is heavier than water (density = 1.469 g/mL).



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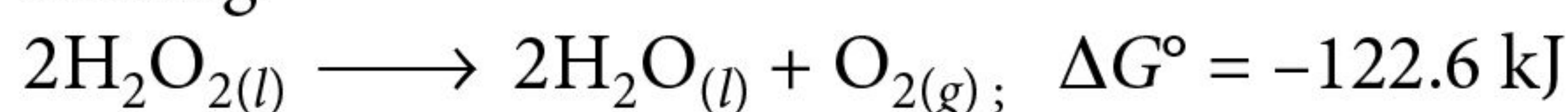
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- It melts at 272.4 K (-0.7°C) and boils under 760 mm of Hg pressure at 423.2 K (150°C) with violent decomposition. However, it can be distilled under reduced pressure at 69.2°C .
- It is diamagnetic.
- It behaves as an excellent solvent for electrolytes due to its high dielectric constant (93.7 for pure H_2O_2).
- It is more extensively associated by H-bonding than water.
- Pure hydrogen peroxide is weakly acidic in nature while its aqueous solution is neutral.

Chemical Properties of Hydrogen Peroxide

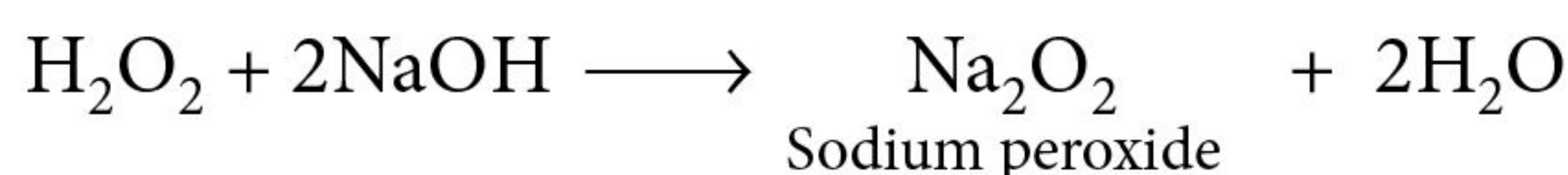
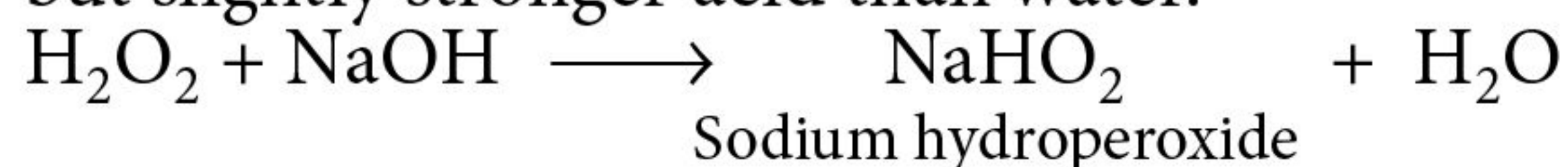
- Hydrogen peroxide acts as oxidant as well as a reductant in both acidic and alkaline solutions. The oxidation state of oxygen in hydrogen peroxide is -1 . It can therefore, be oxidized to O_2 (zero oxidation state) or reduced to H_2O or OH^- (-2 oxidation state for oxygen). However, hydrogen peroxide is a very powerful oxidizing agent and a poor reducing agent.

- **Stability :** Thermodynamically, hydrogen peroxide is unstable and decomposes on long standing or heating.

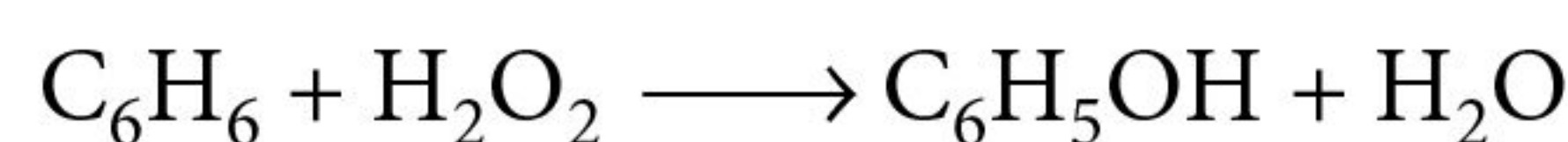
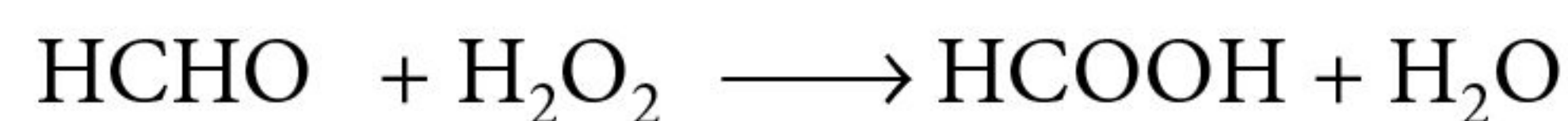
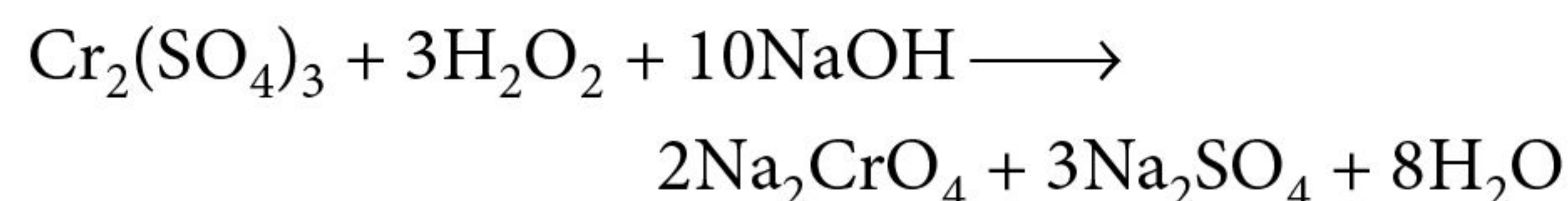
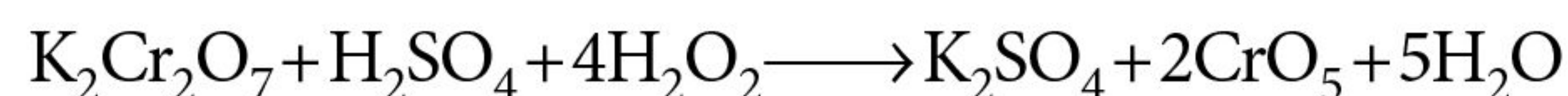
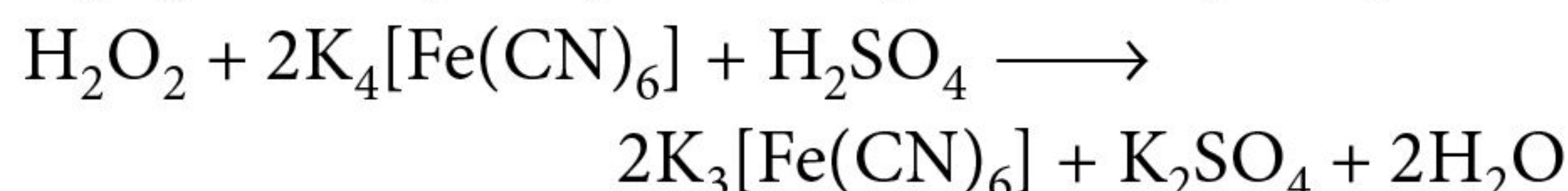
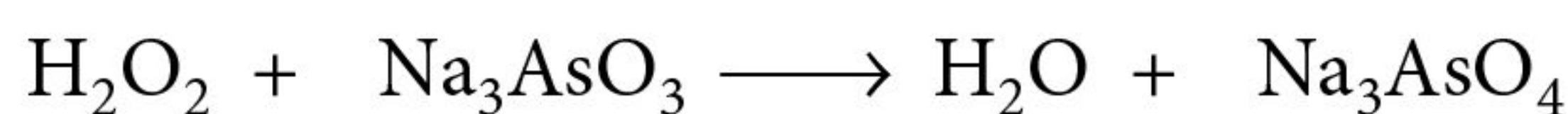
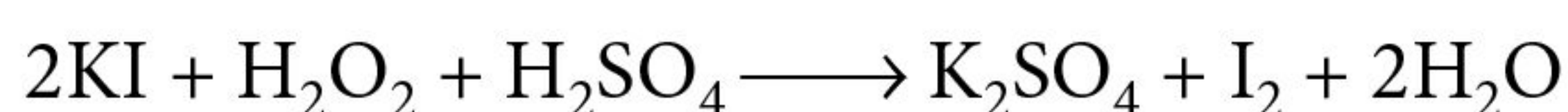
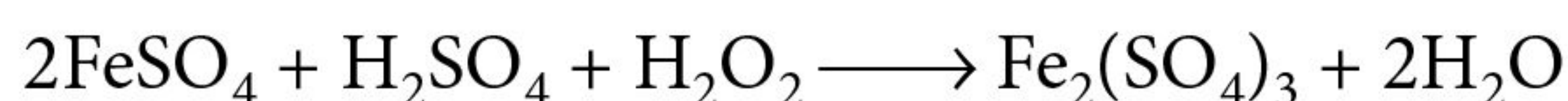
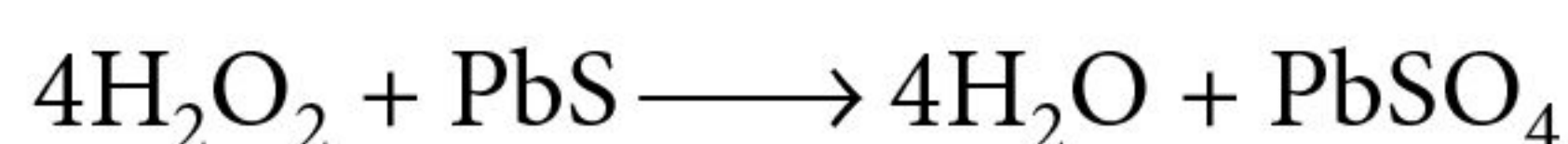
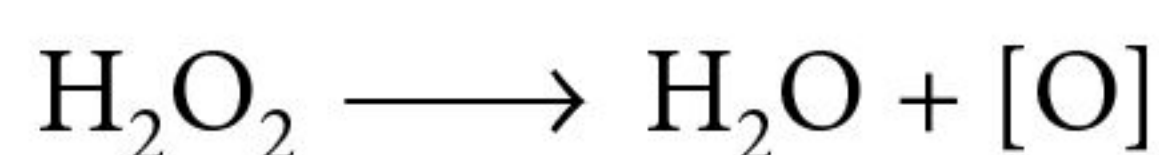


It is an example of auto oxidation-reduction reaction. Platinum, silver, copper, cobalt, manganese dioxide, iron, etc., accelerate its decomposition. There are also a few stabilizers such as : acids, acetanilide, stannates and pyrophosphates. H_2O_2 is not stored in glass bottle since alkali metal oxides present in glass catalyse its decomposition. It is stored in paraffin wax coated glass, plastic or teflon bottles.

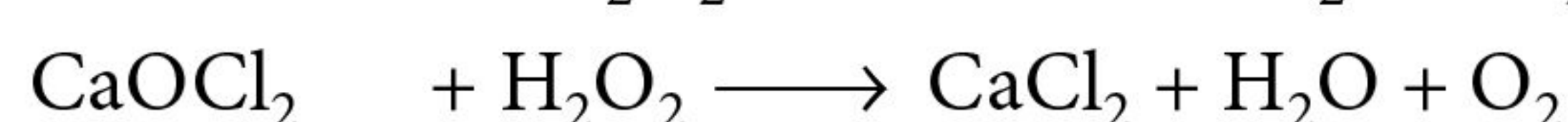
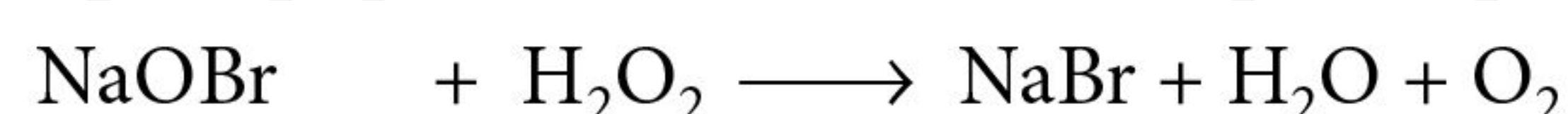
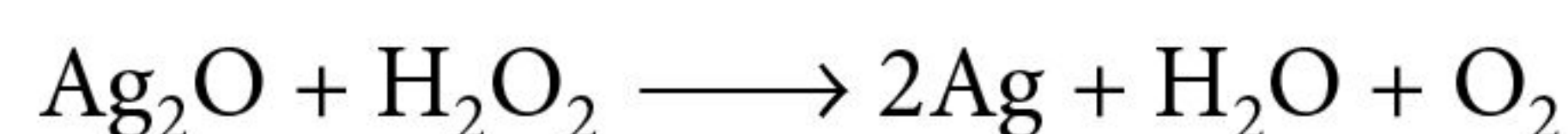
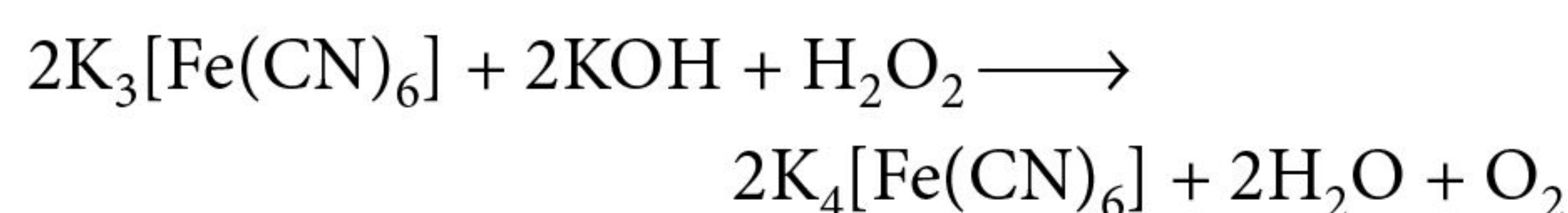
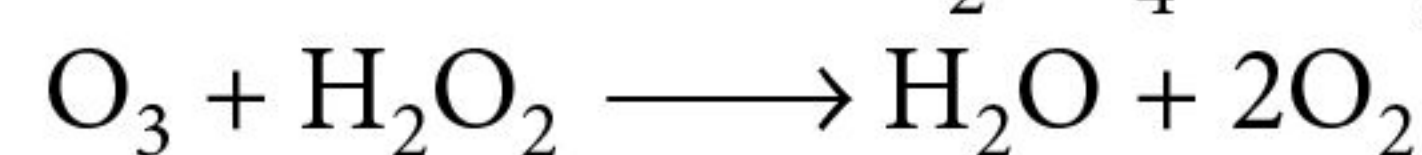
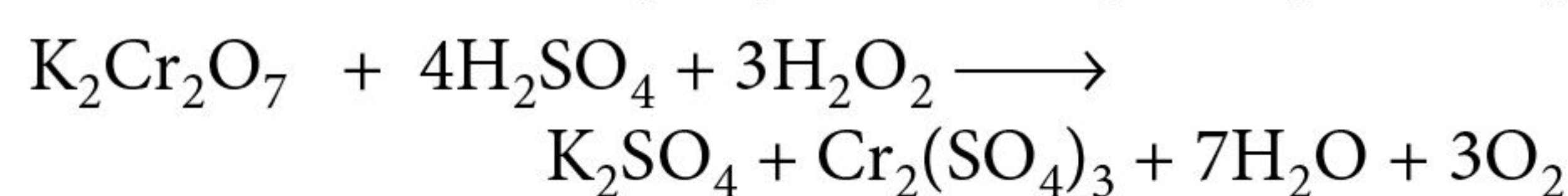
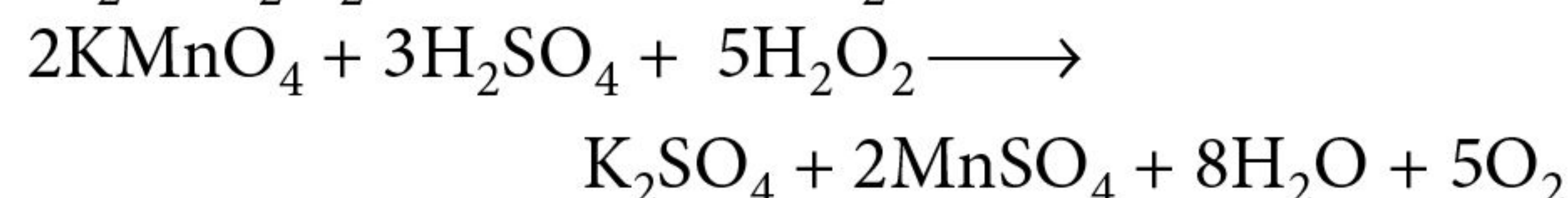
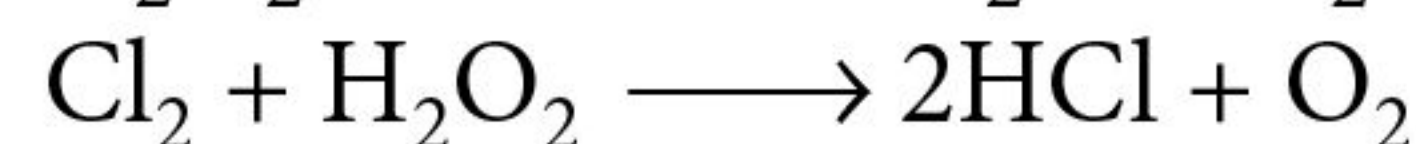
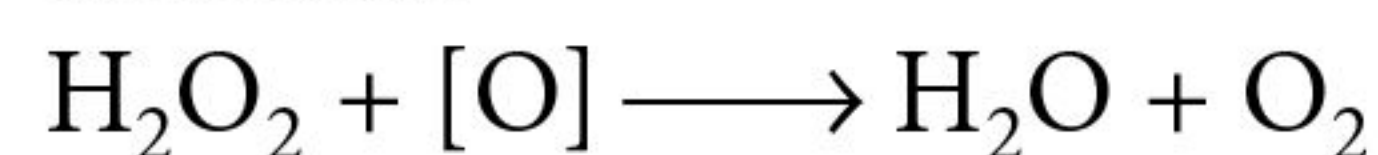
- **Acidic nature :** Hydrogen peroxide is a weak acid but slightly stronger acid than water.



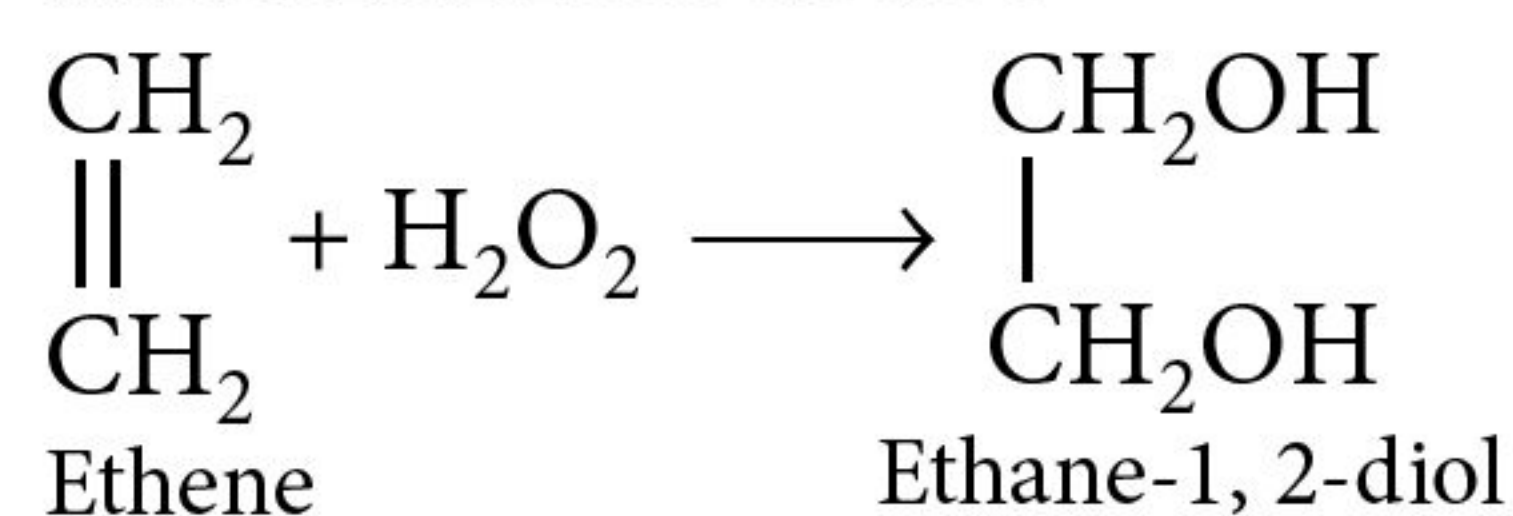
- **Oxidizing properties :** It acts as a strong oxidizing agent in acidic as well as alkaline solution, since it provides nascent oxygen readily.



- **Reducing properties :** In the presence of other strong oxidizing agents, hydrogen peroxide acts as a reducing agent both in acidic as well as alkaline medium.

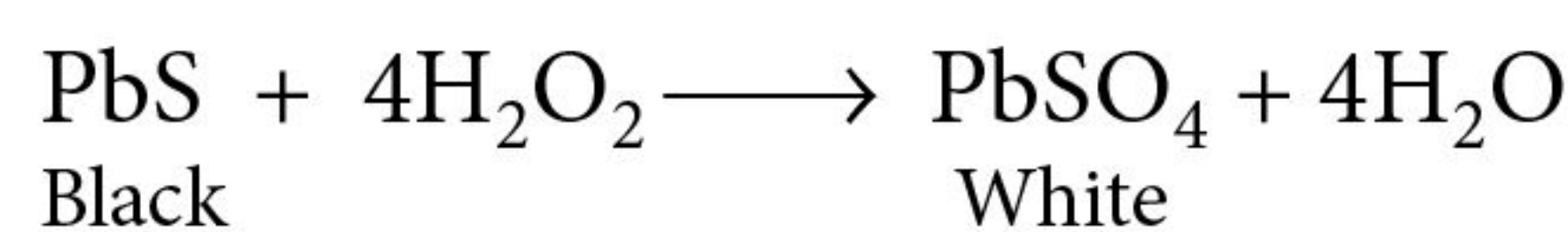


- **Addition reactions :**



Uses of Hydrogen Peroxide

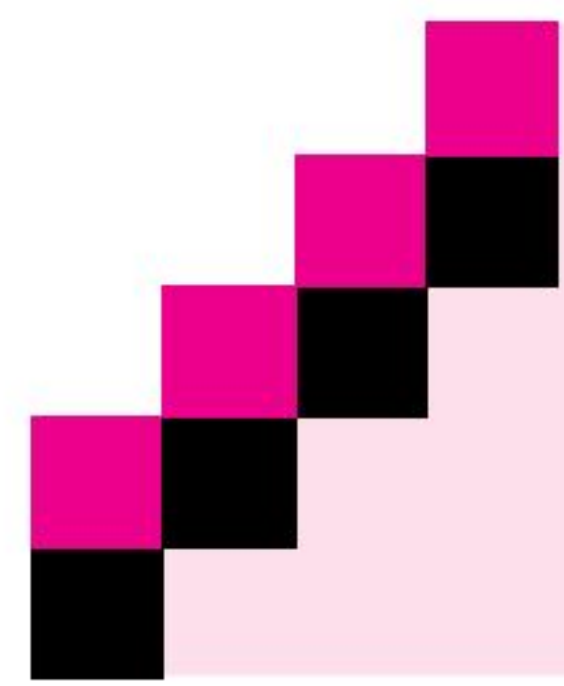
- As a mild bleaching agent, as an antiseptic.
- It restores the colour of the old lead paintings blackened by the action of H_2S . It oxidises the lead sulphide (black) to lead sulphate (white).



- As an oxidizing agent in laboratory and as an antichlor in textile industry.
- As an oxidant for rocket fuel.
- Used to control pollution.

Strength of Hydrogen Peroxide Solution

Volume strength of H_2O_2 means the volume of O_2 released by decomposition of 1 volume H_2O_2 . For example, H_2O_2 of x volume strength means 1 mL or 1 L of H_2O_2 on decomposition gives x mL or x L of oxygen respectively.



WRAP it up!

MULTIPLE CHOICE QUESTIONS

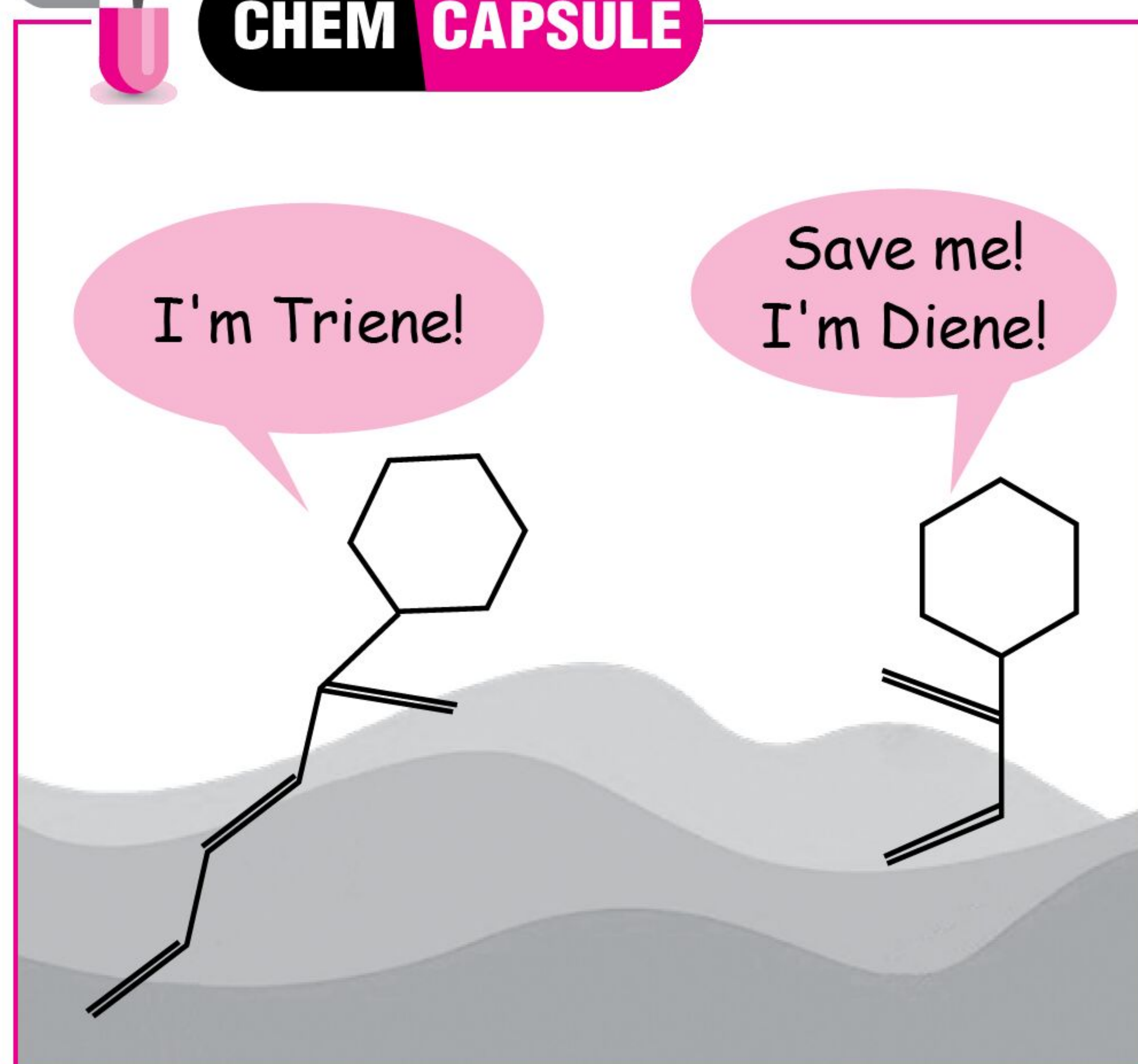
1. A 2.5 mol of hydrazine N_2H_4 loses 25 mole of electrons to form a new compound X. Assuming that all of the nitrogen appears in the new compound, what is the oxidation state of nitrogen in compound X?
(a) -1 (b) -2 (c) +3 (d) +4.
2. The oxidation states of sulphur in the anions SO_3^{2-} , $\text{S}_2\text{O}_4^{2-}$ and $\text{S}_2\text{O}_6^{2-}$ follow the order
(a) $\text{SO}_3^{2-} < \text{S}_2\text{O}_4^{2-} < \text{S}_2\text{O}_6^{2-}$
(b) $\text{S}_2\text{O}_4^{2-} < \text{S}_2\text{O}_6^{2-} < \text{SO}_3^{2-}$
(c) $\text{S}_2\text{O}_6^{2-} < \text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-}$
(d) $\text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-} < \text{S}_2\text{O}_6^{2-}$.
3. The reaction involved during the removal of temporary hardness of water is
(a) $2\text{CaCl}_2 + (\text{NaPO}_3)_6 \rightarrow \text{Na}_2(\text{Ca}_2(\text{PO}_3)_6) + 4\text{NaCl}$
(b) $\text{CaCl}_2 + \text{Na}_2\text{CO}_3 \rightarrow \text{CaCO}_3 + 2\text{NaCl}$
(c) $\text{MgSO}_4 + \text{Na}_2\text{Al}_2\text{Si}_2\text{O}_8 \cdot x\text{H}_2\text{O} \rightarrow \text{MgAl}_2\text{Si}_2\text{O}_8 \cdot x\text{H}_2\text{O} + \text{Na}_2\text{SO}_4$
(d) $\text{Ca}(\text{HCO}_3)_2 \xrightarrow{\Delta} \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2$
4. Match the column I with column II and mark the appropriate choice.
- | Column I | | Column II | |
|----------|------------------------|-----------|----------------------------|
| (A) | NaH | (i) | Interstitial hydride |
| (B) | CH_4 | (ii) | Electron precise hydride |
| (C) | $\text{VH}_{0.56}$ | (iii) | Ionic hydride |
| (D) | B_2H_6 | (iv) | Electron-deficient hydride |
- (a) (A) $\rightarrow$ (iii), (B) $\rightarrow$ (iv), (C) $\rightarrow$ (ii) (D) $\rightarrow$ (i)
(b) (A) $\rightarrow$ (ii), (B) $\rightarrow$ (iv), (C) $\rightarrow$ (iii), (D) $\rightarrow$ (i)
(c) (A) $\rightarrow$ (i), (B) $\rightarrow$ (ii), (C) $\rightarrow$ (iv), (D) $\rightarrow$ (iii)
(d) (A) $\rightarrow$ (iii), (B) $\rightarrow$ (ii), (C) $\rightarrow$ (i), (D) $\rightarrow$ (iv)
5. In aqueous alkaline solution, two electron reduction of HO_2^- gives
(a) HO^- (b) H_2O (c) O_2 (d) O_2^-
6. Hydrogen at room temperature contains
(a) 25% *ortho* + 75% *para*
(b) 25% *para* + 75% *ortho*
(c) 50% *ortho* + 50% *para*
(d) 66% *ortho* + 34% *para*
7. In solid ice, oxygen atom is surrounded
(a) tetrahedrally by 4 hydrogen atoms
(b) octahedrally by 2 oxygen and 4 hydrogen atoms
(c) tetrahedrally by 2 hydrogen and 2 oxygen atoms
(d) octahedrally by 6 hydrogen atoms.
8. What is the value of carbonate hardness of water sample if 100 mL of it took 5 mL of 0.09 N HCl solution? (Molecular weight of Na_2CO_3 = 106 g/mol)
(a) 4.50 mg-eq/L (b) 1.80 mg-eq/L
(c) 0.042 mg-eq/L (d) 477.00 mg-eq/L
9. The correct order of increasing oxidising power in the series is
(a) $\text{VO}_2^+ < \text{Cr}_2\text{O}_7^{2-} < \text{MnO}_4^-$
(b) $\text{Cr}_2\text{O}_7^{2-} < \text{VO}_2^+ < \text{MnO}_4^-$
(c) $\text{Cr}_2\text{O}_7^{2-} < \text{MnO}_4^- < \text{VO}_2^+$
(d) $\text{MnO}_4^- < \text{Cr}_2\text{O}_7^{2-} < \text{VO}_2^+$



CHEM CAPSULE

I'm Triene!

Save me!
I'm Diene!



10. Match the reactions given in column I with average oxidation numbers given in column II.

Column I		Column II	
(A)	$\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$	(P)	$\frac{12}{5}$
(B)	$\text{Fe}_2[\text{Fe}(\text{CN})_6]$	(Q)	2
(C)	$\text{Fe}_3[\text{Fe}(\text{CN})_6]_2$	(R)	$\frac{18}{7}$
(D)	$\text{Fe}[\text{Fe}(\text{CN})_6]$	(S)	1
(E)	$[\text{Fe}(\text{NO})(\text{H}_2\text{O})_5]\text{SO}_4$	(T)	3

- (a) (A) – (P), (B) – (Q), (C) – (R), (D) – (S), (E) – (T)
 (b) (A) – (P), (B) – (Q), (C) – (R), (D) – (T), (E) – (S)
 (c) (A) – (R), (B) – (Q), (C) – (P), (D) – (T), (E) – (S)
 (d) (A) – (Q), (B) – (P), (C) – (R), (D) – (S), (E) – (T)
11. In which of the following reactions, hydrogen peroxide acts as an oxidizing agent?
 (a) $\text{I}_2 + \text{H}_2\text{O}_2 + 2\text{OH}^- \rightarrow 2\text{I}^- + 2\text{H}_2\text{O} + \text{O}_2$
 (b) $\text{PbS} + 4\text{H}_2\text{O}_2 \rightarrow \text{PbSO}_4 + 4\text{H}_2\text{O}$
 (c) $2\text{MnO}_4^- + 3\text{H}_2\text{O}_2 \rightarrow 2\text{MnO}_2 + 3\text{O}_2 + 2\text{H}_2\text{O} + 2\text{OH}^-$
 (d) $\text{HOCl} + \text{H}_2\text{O}_2 \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- + \text{O}_2$
12. Which one of the following processes will produce permanent hardness in water?
 (a) Saturation of water with CaCO_3
 (b) Saturation of water with MgCO_3
 (c) Saturation of water with CaSO_4
 (d) Addition of Na_2SO_4 to water
13. What is the product of the reaction of H_2O_2 with Cl_2 ?
 (a) $\text{O}_2 + \text{HOCl}$ (b) $\text{HCl} + \text{O}_2$
 (c) $\text{H}_2\text{O} + \text{HCl}$ (d) $\text{HCl} + \text{H}_2$
14. **Assertion :** By applying usual method the oxidation number of S in H_2SO_5 (Caro's acid) is +8 but in actual it is +6.
Reason : In H_2SO_5 , there is one peroxy linkage
 (a) Both assertion and reason are true and reason is the correct explanation of assertion.
 (b) Both assertion and reason are true but reason is not the correct explanation of assertion.
 (c) Assertion is true but reason is false.
 (d) Both assertion and reason are false.
15. Given below are few statements regarding electrode potentials. Mark the correct statements.
 (i) The potential associated with each electrode is known as electrode potential.
 (ii) A negative E° means that the redox couple is a stronger reducing agent than H^+ / H_2 couple.

(iii) A positive E° means that the redox couple is a weaker reducing agent than H^+ / H_2 couple.

- (a) (i) and (ii) only (b) (i) and (iii) only
 (c) (ii) and (iii) only (d) (i),(ii) and (iii)
16. A gas X at 1 atm is bubbled through a solution containing a mixture of 1 M Y^- and 1 M Z^- at 25°C . If the reduction potential of $\text{Z} > \text{Y} > \text{X}$, then,
 (a) Y will oxidize X and not Z
 (b) Y will oxidize Z and not X
 (c) Y will oxidize both X and Z
 (d) Y will reduce both X and Z.
17. The volume strength of 1.5 N H_2O_2 solution is
 (a) 4.8 (b) 8.4 (c) 3.0 (d) 8.0
18. **Statement-I :** The alkali metals can form ionic hydrides which contain the hydride ion H^- .
Statement-II : The alkali metals have low electronegativity; their hydrides conduct electricity when fused and liberate hydrogen at the anode.
 (a) Both statement-I and statement-II are correct.
 (b) Both statement-I and statement-II are incorrect.
 (c) Statement-I is correct, statement-II is incorrect.
 (d) Statement-I is incorrect, statement-II is correct.
19. Which of the given compounds can enhance the efficiency of hydrogen storage tank?
 (a) Li/P_4
 (b) Di-isobutylaluminium hydride
 (c) SiH_4 (d) NaNi_5
20. **Assertion :** HNO_3 acts only as oxidising agent while HNO_2 can act both as a reducing agent and an oxidising agent.
Reason : In HNO_3 , oxidation state of nitrogen is +5 which is maximum. In HNO_2 , oxidation state of nitrogen is +3 which can change from –3 to +5.
 (a) Both assertion and reason are true and reason is the correct explanation of assertion.
 (b) Both assertion and reason are true but reason is not the correct explanation of assertion.
 (c) Assertion is true but reason is false.
 (d) Both assertion and reason are false.

NUMERICAL VALUE TYPE QUESTIONS

21. Consider the following equations:
 $2\text{Fe}^{2+} + \text{H}_2\text{O}_2 \longrightarrow x\text{A} + y\text{B}$ (in basic medium)
 $2\text{MnO}_4^- + 6\text{H}^+ + 5\text{H}_2\text{O}_2 \longrightarrow x'\text{C} + y'\text{D} + z'\text{E}$ (in acidic medium)

The sum of the stoichiometric coefficients x, y, x', y' and z' for products A, B, C, D and E respectively, is _____.

22. The difference in the oxidation numbers of the two types of sulphur atoms in $\text{Na}_2\text{S}_4\text{O}_6$ is _____.

23. Calgon, which is used as water softener, has the formula $\text{Na}_y[\text{Na}_x(\text{PO}_3)_6]$. What is the value of $x + y$?

24. In the following reaction

$$x\text{Zn} + y\text{HNO}_3(\text{dil.}) \longrightarrow a\text{Zn}(\text{NO}_3)_2 + b\text{H}_2\text{O} + c\text{NH}_4\text{NO}_3$$

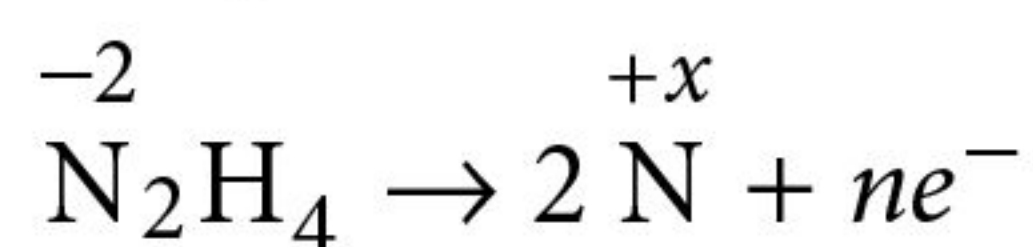
What is the sum of the coefficients ($a + b + c$)?

25. How many of the following are examples of interstitial hydride?

$\text{HF}, \text{H}_2\text{S}, \text{LaH}_3, \text{ZrH}_2, \text{LiH}, \text{CaH}_2$

SOLUTIONS

1. (c) : Suppose the oxidation number of N in new compound X be x .



Suppose no. of electrons lost per mole = n

$$\therefore 2(-2) = 2x + n(-1)$$

$$\text{or } n = 2x + 4 = 2(x + 2)$$

$$\therefore \text{No. of electron lost per mole} = 2(x + 2).$$

$$\text{No. of electrons lost by 2.5 mole} = 2.5 \times 2(2 + x)$$

$$\text{Now, } 2.5 \times 2(2 + x) = 25$$

$$5(2 + x) = 25$$

$$\text{or } 2 + x = 5 \text{ or } x = +3$$

2. (d) : $\text{SO}_3^{2-} \rightarrow x + 3(-2) = -2; x - 6 = -2;$

$$x = +4$$

$$\text{S}_2\text{O}_4^{2-} \rightarrow 2x + 4(-2) = -2; 2x - 8 = -2; x = +3$$

$$\text{S}_2\text{O}_6^{2-} \rightarrow 2x + 6(-2) = -2; 2x - 12 = -2; x = +5$$

$$\text{Therefore } \text{S}_2\text{O}_4^{2-} < \text{SO}_3^{2-} < \text{S}_2\text{O}_6^{2-}$$

3. (d) : Temporary hardness of water is due to the presence of bicarbonates of Ca and Mg.

4. (d)

5. (a) : $\text{H}-\text{O}-\text{O}^- + \text{H}_2\text{O} + 2e^- \longrightarrow 3\text{OH}^-$

6. (b) : At room temperature, the ratio of *ortho* to *para* hydrogen is 3 : 1.

7. (a) : X-ray studies have shown that in ice, four hydrogen atoms tetrahedrally surround each oxygen atoms.

8. (a) : Volume of water sample (V_1) = 100 mL;
 Volume of HCl solution (V_2) = 5 mL; Normality of HCl solution (N_2) = 0.09 N

and molecular weight of Na_2CO_3 = 106 g/mol

Normality or hardness of the water sample (N_1)

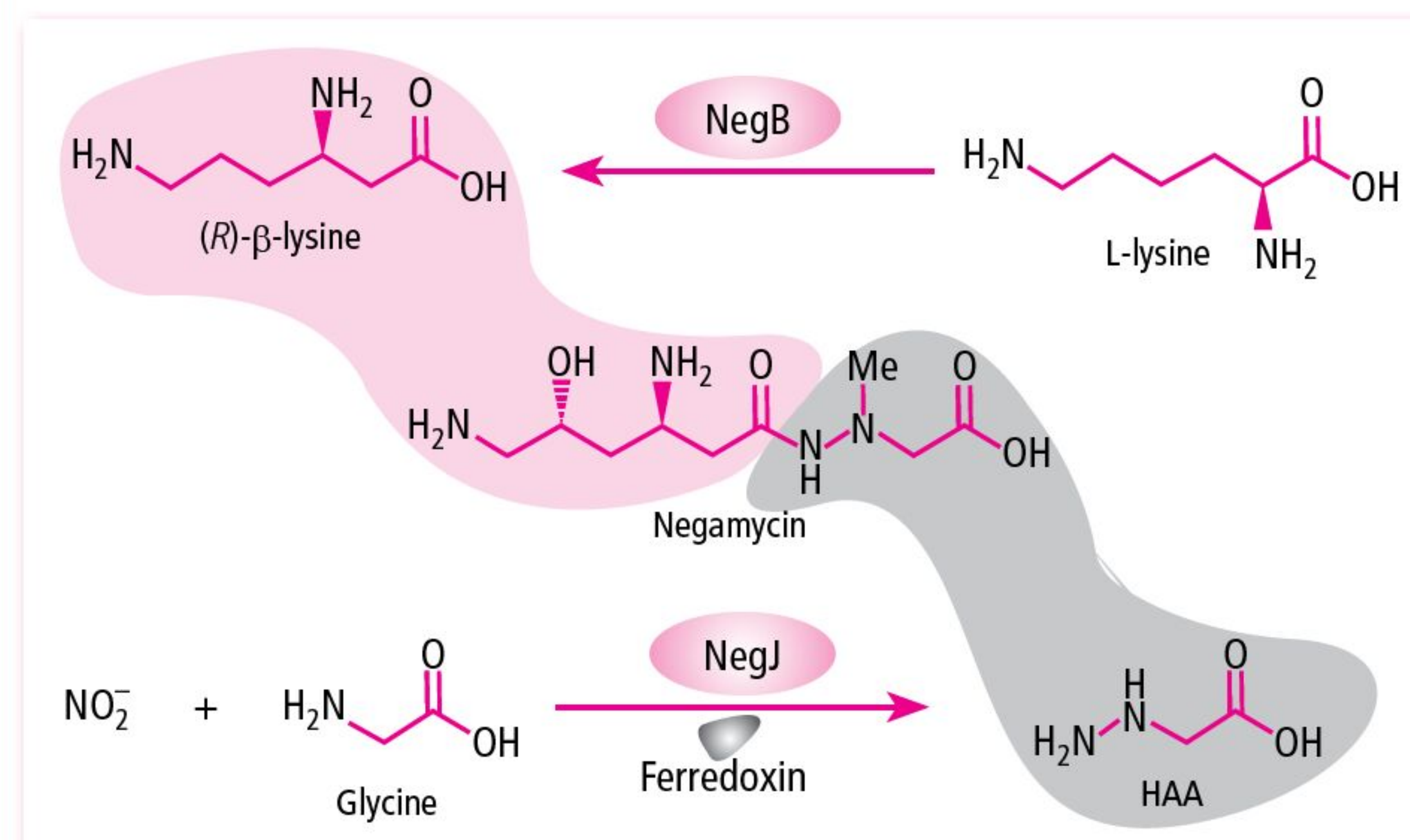
$$= \frac{N_2 \times V_2}{V_1} = \frac{0.09 \times 5}{100}$$

$$= 4.5 \times 10^{-3} \text{ g-eq/L}$$

$$= 4.50 \text{ mg-eq/L}$$

Chemistry bulletin

A heme-dependent enzyme forms the hydrazine in the antibiotic negamycin



Negamycin, a hydrazine-containing dipeptide-like antibiotic, was first isolated in 1970 from three strains of *Streptomyces purpeofuscus*. Its pronounced antibacterial properties render it an appealing candidate for combating multi-drug-resistant Gram-negative bacteria. Additionally, the unique readthrough-promoting activity makes it a subject for research as a potential therapeutic agent for Duchenne muscular dystrophy and other hereditary diseases. Here we use the unusual (*R*)-β-lysine found in negamycin as a guide to identify the biosynthetic pathway of negamycin and then carry out gene deletion and chemical complementation, stable isotope feeding and enzyme assays to elucidate the key precursors for negamycin assembly. Our work identified NegB as a lysine-2,3-aminomutase that converts lysine into (*R*)-β-lysine and NegJ as a heme-dependent, N–N bond-forming enzyme. We show that NegJ, together with a ferredoxin encoded outside of the negamycin gene cluster, directly forms hydrazinoacetic acid from glycine and nitrite. NegJ is a novel biocatalyst for N–N bond formation, and our work highlights its potential for genome mining of N–N bond-containing natural products.

9. (a): Greater the oxidation state, stronger the oxidising power. $\text{VO}_2^+ < \text{Cr}_2\text{O}_7^{2-} < \text{MnO}_4^-$
 $(\text{V}^{5+}) \quad (\text{Cr}^{6+}) \quad (\text{Mn}^{7+})$

10. (c): $(\text{A} \rightarrow \text{R}) \text{Fe}_4^{3+}[\text{Fe}^{2+}(\text{CN})_6]_3$

Average oxidation number of Fe is $\frac{3 \times 4 + 2 \times 3}{7} = \frac{18}{7}$

$(\text{B} \rightarrow \text{Q}) \text{Fe}_2^{+2}[\text{Fe}^{+2}(\text{CN})_6]$

Average oxidation number of Fe is $\frac{2 \times 2 + 2}{3} = \frac{6}{3} = 2$

$(\text{C} \rightarrow \text{P}) \text{Fe}_3^{2+}[\text{Fe}^{3+}(\text{CN})_6]_2$

Average oxidation number of Fe is $\frac{2 \times 3 + 3 \times 2}{5} = \frac{12}{5}$

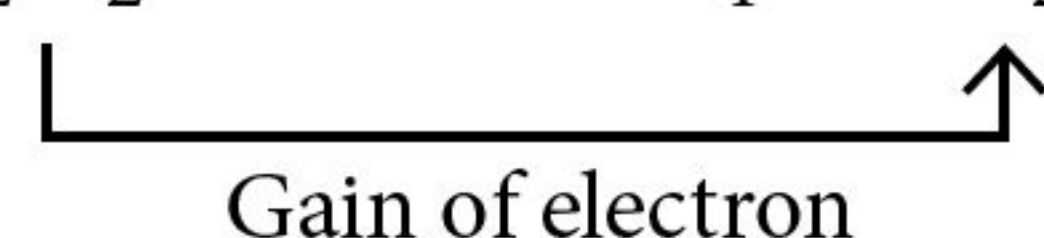
$(\text{D} \rightarrow \text{T}) \text{Fe}^{+3}[\text{Fe}^{+3}(\text{CN})_6]$

Average oxidation number of Fe is $\frac{3 + 3}{2} = \frac{6}{2} = 3$

$(\text{E} \rightarrow \text{S}) [\text{Fe}(\text{NO})(\text{H}_2\text{O})_5]^{2+} \text{SO}_4^{2-}$

Oxidation state of Fe is +1.

11. (b): $\text{PbS} + 4\text{H}_2\text{O}_2 \longrightarrow \text{PbSO}_4 + 4\text{H}_2\text{O}$



Since, H_2O_2 gains electron to convert into H_2O . Hence, H_2O_2 acts as an oxidizing agent.

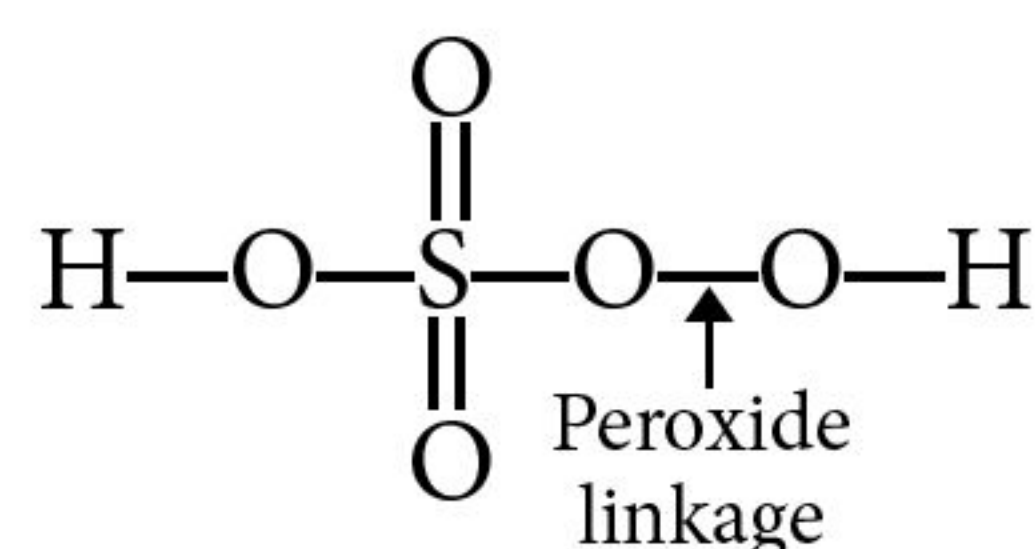
12. (c): Permanent hardness is introduced when water passes over rocks containing the sulphates or chlorides of both calcium and magnesium.

13. (b): $\text{H}_2\text{O}_2 + \text{Cl}_2 \longrightarrow 2\text{HCl} + \text{O}_2$

14. (a): By usual method, H_2SO_5 :

$$2 \times 1 + n + 5 \times (-2) = 0 \Rightarrow n = +8$$

But this cannot be true as the maximum oxidation number of S is +6. H_2SO_5 contain a peroxide linkage as:



Hence, the oxidation of sulphur can be calculated as:

$$\begin{array}{cccc} 2 \times (+1) & + & x & + & 3 \times (-2) & + & 2 \times (-1) \\ (\text{for H}) & & & & (\text{for O}) & & (\text{for O—O in peroxide linkage}) \\ +2 & + & x & -6 & -2 & = & 0; x = +6 \end{array}$$

15. (d)

16. (a): From the given data, it can be concluded that 'Y' will oxidize 'X' and it will not oxidize 'Z'.

17. (b): $2\text{H}_2\text{O}_2 \longrightarrow 2\text{H}_2\text{O} + \text{O}_2$
 $2 \times 34 = 68 \quad \quad \quad 22.4 \text{ L at NTP}$

By 'x' volume of H_2O_2 , we mean that 1 mL of H_2O_2 solution will produce x mL of O_2 at NTP.

The volume of O_2 evolved from 1.5 N H_2O_2 can be found as follows:

Mass of H_2O_2 in 1.5 N solution of H_2O_2
 $= 1.5 \times 17 = 25.5 \text{ g} \quad [\text{eq. wt. of } \text{H}_2\text{O}_2 = 17]$

$\therefore$ Volume of O_2 liberated by 68 g of H_2O_2
 $= 22.4 \text{ L at NTP}$

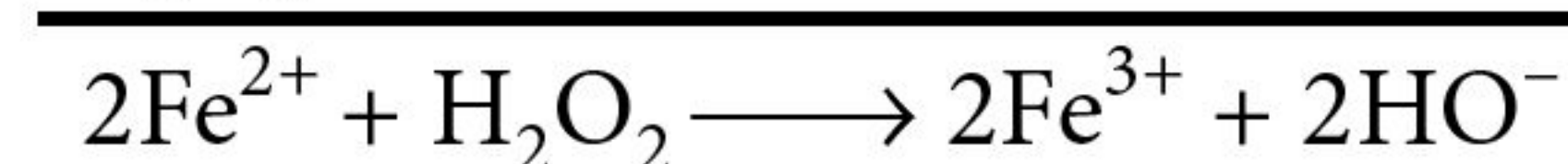
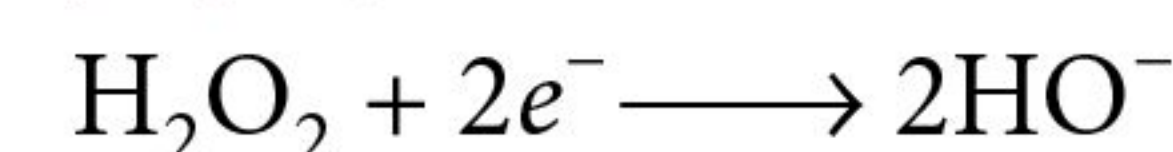
$\therefore$ Volume of O_2 liberated by 25.5 g of H_2O_2
 $= \frac{22.4}{68} \times 25.5 \text{ L} = 8.4 \text{ L}$

18. (a)

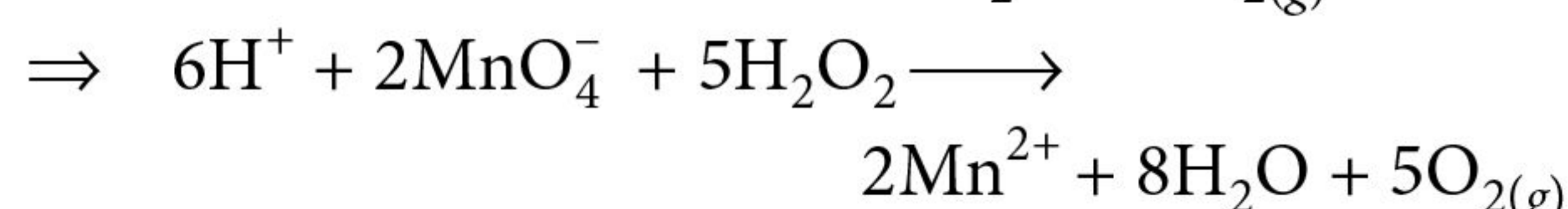
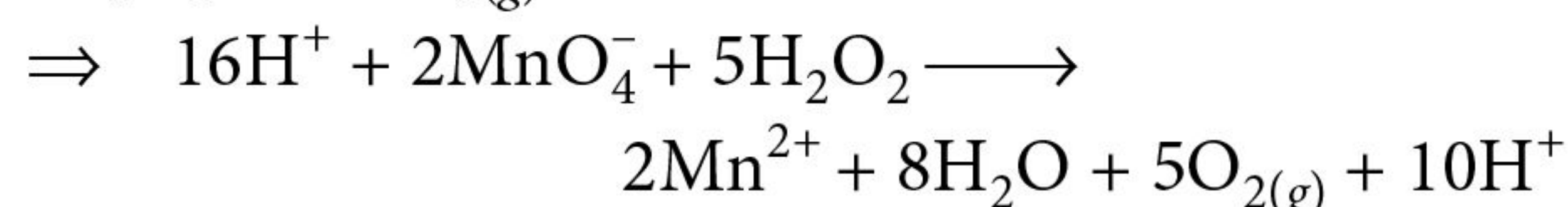
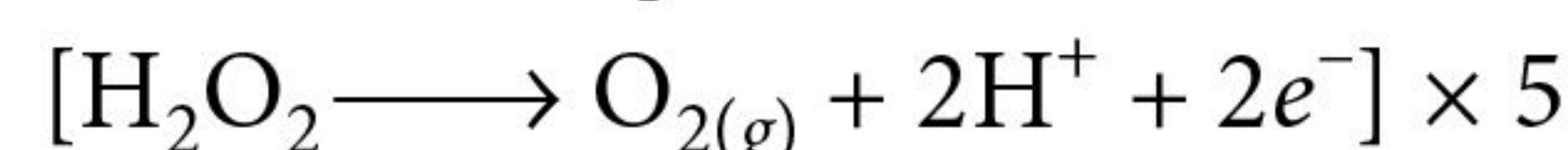
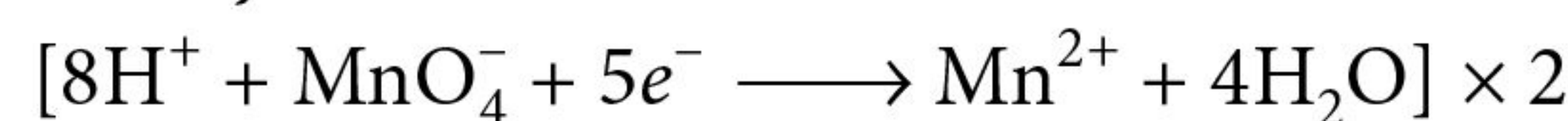
19. (d): Tanks of metal alloys like NaNi_5 , Ti-TiH_2 , Mg-MgH_2 etc., are used for storage of hydrogen.

20. (a): Since in HNO_2 oxidation state of nitrogen can increase or decrease it can act as an oxidising as well as a reducing agent.

21. (19): $[\text{Fe}^{2+} \longrightarrow \text{Fe}^{3+} + e^-] \times 2$

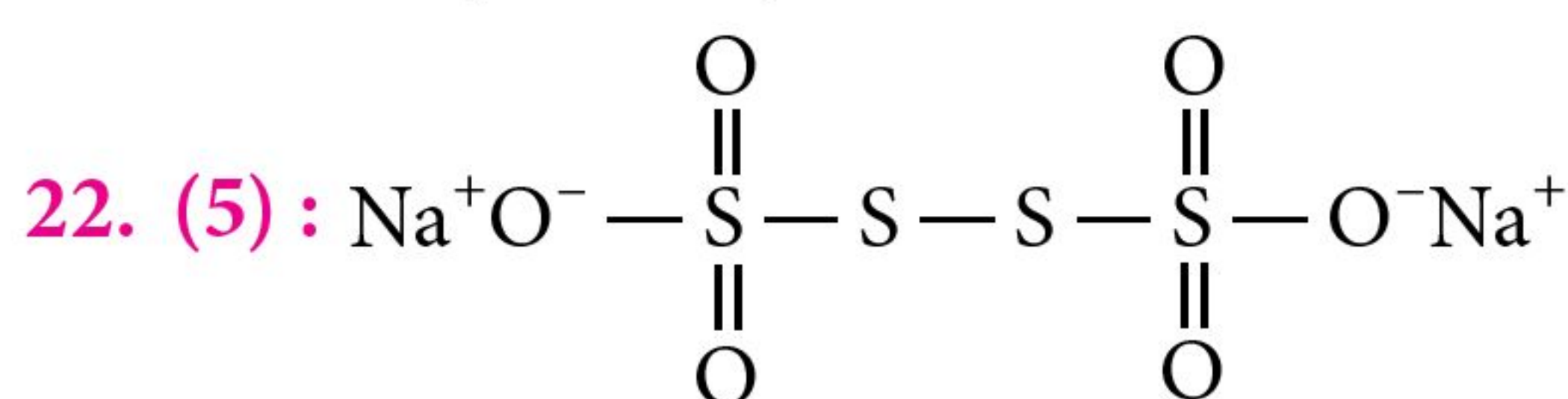


$$x = 2, y = 2$$



$$\text{So } x' = 2, y' = 8, z' = 5$$

$$\text{So } x + y + x' + y' + z' = 2 + 2 + 2 + 8 + 5 = 19$$



S have oxidation number = +5 and 0

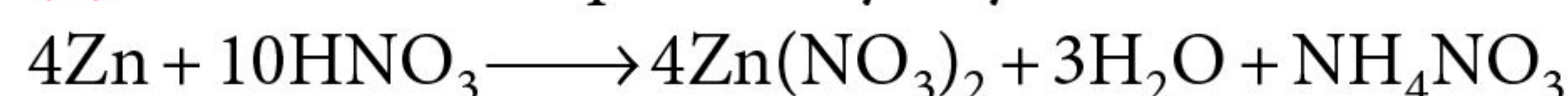
Difference in oxidation no. = 5

23. (6): Calgon has the formula $\text{Na}_2[\text{Na}_4(\text{PO}_3)_6]$.

$\therefore$ The value of x is 4 and that of y is 2.

$$\text{So, } x + y = 6$$

24. (8): Balance the equation by any method.



$$\therefore a + b + c = 4 + 3 + 1 = 8$$

25. (2): LaH_3 and ZrH_2 are examples of interstitial hydrides. ◆◆

Class XI

Monthly test



This specially designed column enables students to self analyse their extent of understanding of all chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

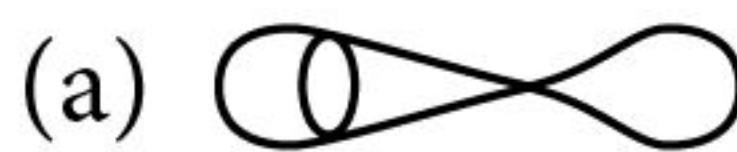
Chemical Bonding and Molecular Structure | Hydrogen

Total Marks : 120

Time taken : 60 Min.

NEET

Only One Option Correct Type

- Among LiCl , BeCl_2 , BCl_3 and CCl_4 , the covalent bond character follows the order
 (a) $\text{BeCl}_2 > \text{BCl}_3 > \text{CCl}_4 < \text{LiCl}$
 (b) $\text{BeCl}_2 < \text{BCl}_3 < \text{CCl}_4 < \text{LiCl}$
 (c) $\text{LiCl} < \text{BeCl}_2 < \text{BCl}_3 < \text{CCl}_4$
 (d) $\text{LiCl} > \text{BeCl}_2 > \text{BCl}_3 > \text{CCl}_4$
- Identify the correct sequence of increasing number of π -bonds in the structures of the following molecules.
 I. $\text{H}_2\text{S}_2\text{O}_6$ II. H_2SO_3 III. $\text{H}_2\text{S}_2\text{O}_5$
 (a) I, II, III (b) II, III, I
 (c) II, I, III (d) I, III, II
- N_2 and O_2 are converted into monocations, N_2^+ and O_2^+ respectively. Which is wrong?
 (a) In O_2^+ , paramagnetism decreases.
 (b) N_2^+ becomes diamagnetic.
 (c) In N_2^+ , the N-N bond weakens.
 (d) In O_2^+ , the O-O bond order increases.
- The number of anti-bonding electron pairs in O_2^{2-} molecular ion on the basis of molecular orbital theory is (Atomic number of O is 8.)
 (a) 3 (b) 2 (c) 5 (d) 4
- The shape of the compounds like ClF_3 , BrF_5 , XeF_4 and SF_4 , respectively, are
 (a) see-saw, square planar, square pyramidal, T-shaped
 (b) T-shaped, square planar, bent, see-saw
 (c) T-shaped, square pyramidal, square planar, see-saw
 (d) square planar, see-saw, T-shaped, square pyramidal.
- If the canonical or resonating structures of a molecule required to describe the structure of a molecule then which of the following rules is obeyed?
 (a) The relative position of all atoms can differ.
 (b) The same number of unpaired and paired electrons in all structures.
 (c) The energy of each structure is different.
 (d) Like charges are present on adjacent atoms.
- The number of lone pairs of electrons on the central atoms of H_2O , SnCl_2 , PCl_3 and XeF_2 respectively, are
 (a) 2, 1, 1, 3 (b) 2, 2, 1, 3
 (c) 3, 1, 1, 2 (d) 2, 1, 2, 3
- Arrange the following in order of increasing dipole moment : H_2O , H_2S , BF_3 .
 (a) $\text{BF}_3 < \text{H}_2\text{S} < \text{H}_2\text{O}$ (b) $\text{H}_2\text{S} < \text{BF}_3 < \text{H}_2\text{O}$
 (c) $\text{H}_2\text{O} < \text{H}_2\text{S} < \text{BF}_3$ (d) $\text{BF}_3 < \text{H}_2\text{O} < \text{H}_2\text{S}$
- Which of the following order is correct?
 (a) $\text{AlCl}_3 < \text{MgCl}_2 < \text{NaCl}$: Polarising power
 (b) $\text{CO} > \text{CO}_2 > \text{HCO}_2^- > \text{CO}_3^{2-}$: Bond length
 (c) $\text{BeCl}_2 < \text{NF}_3 < \text{NH}_3$: Dipole moment
 (d) $\text{H}_2\text{S} > \text{NH}_3 > \text{SiH}_4 > \text{BF}_3$: Bond angle
- p - p overlapping is diagrammatically represented as
 (a)  (b) 
 (c)  (d) 
- According to MO theory which of the lists ranks the nitrogen species in terms of increasing bond order?
 (a) $\text{N}_2^{2-} < \text{N}_2^- < \text{N}_2$ (b) $\text{N}_2 < \text{N}_2^{2-} < \text{N}_2^-$
 (c) $\text{N}_2^- < \text{N}_2^{2-} < \text{N}_2$ (d) $\text{N}_2^- < \text{N}_2 < \text{N}_2^{2-}$

12. In which of the following molecules/ions BF_3 , NO_2^- , NH_2^- and H_2O , the central atom is sp^2 hybridised?
- (a) NH_2^- and H_2O (b) NO_2^- and H_2O
 (c) BF_3 and NO_2^- (d) NO_2 and NH_2^-

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

- (a) If both assertion and reason are true and reason is the correct explanation of assertion.
 (b) If both assertion and reason are true but reason is not the correct explanation of assertion.
 (c) If assertion is true but reason is false.
 (d) If both assertion and reason are false.

13. **Assertion :** C_2H_2 molecule is linear.

Reason : In C_2H_2 , carbon atoms remain unhybridised.

14. **Assertion :** Fluorine molecule has bond order one.

Reason : The number of electrons in the antibonding molecular orbitals is two less than that in bonding molecular orbitals.

15. **Assertion :** The magnitude of hydrogen bonding depends on physical state of the compound.

Reason : *o*-nitrophenol is steam volatile due to intramolecular Hydrogen bonding.

JEE (Main & Advanced)

Only One Option Correct Type

16. Arrange He_2^+ , C_2^{2-} , O_2^- and NO in increasing order of their bond orders.

- (a) $\text{NO} < \text{O}_2^- < \text{C}_2^{2-} < \text{He}_2^+$
 (b) $\text{O}_2^- < \text{NO} < \text{C}_2^{2-} < \text{He}_2^+$
 (c) $\text{C}_2^{2-} < \text{He}_2^+ < \text{O}_2^- < \text{NO}$
 (d) $\text{He}_2^+ < \text{O}_2^- < \text{NO} < \text{C}_2^{2-}$

17. Which of the following are saline hydrides?

- I. CsH II. H_2Se III. KH IV. BaH_2
 (a) I, II and IV (b) I, III and IV
 (c) II, III and IV (d) II and IV

18. Carbon atoms in $\text{C}_2(\text{CN})_4$ are

- (a) sp hybridised (b) sp^2 hybridised
 (c) sp and sp^2 hybridised
 (d) sp , sp^2 and sp^3 hybridised.

19. The processes that are not suitable for the removal of permanent hardness of water are

- (I) treatment with sodium carbonate
 (II) Calgon's method
 (III) Clark's method
 (IV) ion-exchange method
 (V) boiling

- (a) I, II and V (b) II, III and IV
 (c) III and V (d) I, II, IV and V

More than One Option Correct Type

20. Select the incorrect statement(s).

- (a) H_2O_2 can be prepared commercially by partial oxidation of 2-propanol.
 (b) Old lead paintings regain their original colour by washing with hydrogen peroxide solution.
 (c) H_2O_2 has basic properties and behaves as a weak base.
 (d) Decomposition of H_2O_2 is accelerated by alcohol.

21. Which of the following conditions apply to resonating structures?

- (a) Identical arrangement of atoms
 (b) Nearly same energy content
 (c) Identical number of bonds
 (d) Same number of unpaired electrons

22. Which of the following statements is/are not correct for D_2O ?

- (a) Its boiling point is higher than H_2O .
 (b) The solubility of NaCl in it is more than H_2O .
 (c) D_2O reacts faster than H_2O .
 (d) The viscosity is higher than H_2O at 25°C .

23. According to molecular orbital theory,

- (a) C_2^{2-} is expected to be diamagnetic
 (b) O_2^{2+} is expected to have a longer bond length than O_2
 (c) N_2^+ and N_2^- have the same bond order
 (d) He_2^+ has the same energy as two isolated He atoms.

Integer / Numerical Value Type

24. Among H_2 , He_2^+ , Li_2 , Be_2 , B_2 , C_2 , N_2 , O_2^- and F_2 the number of diamagnetic species is _____.

(Atomic numbers: $\text{H} = 1$, $\text{He} = 2$, $\text{Li} = 3$, $\text{Be} = 4$, $\text{B} = 5$, $\text{C} = 6$, $\text{N} = 7$, $\text{O} = 8$, $\text{F} = 9$)

25. The strength of 50 volume solution of hydrogen peroxide is _____ g/L. (Nearest integer).

Given : Molar mass of H_2O_2 is 34 g mol^{-1} .

Molar volume of gas at STP = 22.7 L .

26. In how many of the following ionisation processes, both the bond order and the magnetic behaviour are changed?

- (i) $\text{O}_2 \rightarrow \text{O}_2^+$ (ii) $\text{CN} \rightarrow \text{CN}^-$
 (iii) $\text{NO} \rightarrow \text{NO}^+$ (iv) $\text{N}_2 \rightarrow \text{N}_2^+$
 (v) $\text{C}_2 \rightarrow \text{C}_2^+$ (vi) $\text{CO} \rightarrow \text{CO}^+$

Comprehension Type

The electrons in an atom occupy atomic orbitals which are represented as the regions around the nuclei where there is a high probability of finding the electrons. Molecular orbital theory is based on the linear combination of atomic orbitals (LCAO) of the atoms constituting the molecule or ion and hence is also called LCAO-MO theory. In this theory, atomic orbitals of the combining atoms get mixed and rearrange themselves to form molecular orbitals. Two atomic orbitals can overlap to form two molecular orbitals – one of which lies at a lower energy level, called bonding molecular orbital (BMO) than the other at a higher energy level, called antibonding molecular orbital (ABMO). The sequence of the rearrangement of molecular orbitals is determined by the two nuclei and the filling of electron in them follow the Aufbau principle. Each molecular orbital can hold one or two electrons in accordance with Pauli's exclusion principle. The bond order of a molecule or ion is half the number of bonding electrons minus the number of antibonding electrons. Molecular orbital theory can explain the bond length, bond dissociation energy, bond stability and paramagnetism/diamagnetism of molecules.

27. On the basis of MO theory which one of the following species does not exist?
 (a) He_2^{2+} (b) He_2 (c) He_2^+ (d) Li_2^+
28. During change of $\text{NO}^+ \rightarrow \text{NO}$, the electron is added to
 (a) σ -orbital (b) π -orbital
 (c) σ^* -orbital (d) π^* -orbital.

Matching Type

29. Match the column I with column II and select the correct option.

Column I		Column II	
A.	Paramagnetic	P.	CO
B.	Trigonal bipyramidal structure	Q.	CO^+
C.	Triangular planar structure	R.	BF_3
D.	Bond order is three	S.	PCl_5

- (a) A – P, B – R, C – S, D – Q
 (b) A – Q, B – S, C – R, D – P
 (c) A – Q, B – S, C – P, D – R
 (d) A – P, B – S, C – R, D – Q

30. Match the column I with column II and select the correct option.

Column I		Column II	
A.	H_2O	P.	Zeolite
B.	Electrolysis of water	Q.	Can be reduced to dihydrogen by NaH
C.	Heavy water	R.	Sodium hexameta phosphate
D.	Used in calgon method	S.	Hydrogen and oxygen
		T.	Used in atomic reactor

- (a) A – Q, B – S, C – T, D – R
 (b) A – Q, B – S, C – T, D – P
 (c) A – T, B – S, C – Q, D – P, R
 (d) A – Q, B – S, C – Q, D – R



CHEM CAPSULE

WHAT DO YOU GET WHEN YOU
MIX SULPHUR, TUNGSTEN,
AND SILVER?

$\begin{matrix} 16 \\ 32.06 \\ \text{S} \\ \text{Sulphur} \end{matrix}$	$\begin{matrix} 74 \\ 183.84 \\ \text{W} \\ \text{Tungsten} \end{matrix}$	$\begin{matrix} 47 \\ 107.87 \\ \text{Ag} \\ \text{Silver} \end{matrix}$
---	---	--

SWAG!

Keys are published in this issue. Search now! 😊

SELF CHECK

No. of questions attempted
 No. of questions correct
 Marks scored in percentage

Check your score! If your score is

> 90%	EXCELLENT WORK !	You are well prepared to take the challenge of final exam.
90-75%	GOOD WORK !	You can score good in the final exam.
74-60%	SATISFACTORY !	You need to score more next time.
< 60%	NOT SATISFACTORY!	Revise thoroughly and strengthen your concepts.



IMPORTANT DAYS AND DATES

- National Doctors' Day is celebrated on 1 July every year in India since 1991 to honour the legacy of Dr. Bidhan Chandra Roy, a renowned physician, freedom fighter, and former Chief Minister of West Bengal. He was born on 1 July 1882, and interestingly, also passed away on the same date in 1962. He played a pivotal role in shaping India's healthcare landscape and was instrumental in establishing esteemed medical institutions and received the Bharat Ratna, the country's highest civilian award, for his service.
- National Postal Worker Day, also known as National Postal Day, is observed annually on 1 July. It is dedicated to recognize and appreciate the hard work and dedication of postal workers who ensure the delivery of mail and packages to homes and businesses and acknowledge the important role postal workers play in connecting people and communities.
- Chartered Accountants Day or simply CA Day is celebrated annually on 1 July to recognize the significant contributions of Chartered Accountants to the nation's financial and economic growth. This day marks the establishment of the Institute of Chartered Accountants of India (ICAI) on 1 July 1949.
- World Population Day is an annual event which is observed on 11 July to raise awareness of global population issues. The event was established by the Governing Council of the United Nations Development Programme in 1989. The 2025 theme will focus on safeguarding the health and rights of girls and women, emphasizing maternal healthcare, reproductive rights, and women's empowerment. The day will also highlight the need to address demographic challenges as the world's population continues to evolve, emphasizing the power of informed choices and equitable opportunities for all.
- World Day for International Justice, also referred to as Day of International Criminal Justice or International Justice Day, is an international day celebrated throughout the world on 17 July as part of an effort to recognize the emerging system of international criminal justice.
- Nelson Mandela International Day is an annual international day celebrated in honour of Nelson Mandela on 18 July, Mandela's birthday. The day was officially declared by the United Nations in November 2009, with the first UN Mandela Day on 18 July 2010.
- International Moon Day was declared on 9 December 2021 by the United Nations General Assembly (UNGA), building upon the recommendation of the Committee on the Peaceful Uses of Outer Space. This commemorative day is observed annually on 20 July. This day was chosen to honour the anniversary of the first landing of humans on the Moon. This marked a historic feat in Moon exploration and paved the way for future research and discovery.
- International Chess Day is celebrated annually on 20 July, the day the FIDE was founded, in 1924. The idea was proposed by UNESCO, and it has been celebrated as such since 1966. FIDE, which has 171 chess federations as its members, organizes chess events and competitions around the world on this day. Mathematically, there are more possible games of chess than there are atoms in the Observable Universe.

- World Nature Conservation Day is observed annually on 28 July. It is dedicated to raising awareness about the importance of protecting our planet's natural resources and ecosystems. The day emphasizes the need for sustainable practices to ensure a healthy environment for future generations.
- Global Tiger Day, often called International Tiger Day, is an annual celebration to raise awareness

for tiger conservation, held annually on 29 July. It was created in 2010 at the Saint Petersburg Tiger Summit in Russia by Vladimir Putin, who has made it his mission to save the Amur tiger. The main aim is to urge the international community to intensify efforts for wildlife protection through expanding protected areas, promoting sustainable livelihoods, and maintaining sufficient forest area in tiger roaming nations.

Test Yourself!

- The World Sports Journalists Day is celebrated on
(a) 2 July (b) 14 January
(c) 31 December (d) 12 June
- Which of the following is not a tiger range country?
(a) India (b) Australia
(c) Russia (d) Vietnam
- International Chess Day is celebrated annually on 20 July since
(a) 1983 (b) 1999
(c) 1950 (d) 1966
- Which of the following celebrates its Independence Day on 4 July?
(a) United Kingdom (b) China
(c) United States (d) Russia
- 22 July is celebrated for the king of fruits as
(a) World Mango Day
(b) World Apple Day
(c) International Banana Day
(d) International Pomegranate Day
- When is Nelson Mandela's birthday?
(a) 17 July (b) 18 July
(c) 15 July (d) 16 July
- In India, National Doctors' Day is celebrated to honour the legacy of
(a) Dr. K.M. Cherian
(b) Dr. Mathew Samuel Kalarickal
(c) Dr. Rakesh Kumar
(d) Dr. Bidhan Chandra Roy
- Which of the following days is celebrated every year on 6 July, to recall the importance of raising public awareness about the risk that certain diseases of animal origin can affect human health and vice versa?
(a) World Health Day
(b) World Zoonoses Day
(c) World Animal Disease Day
(d) Human Health Day
- FIDE stands for
(a) Federation of International Diplomatic Encouragement
(b) First in Defense of Earth
(c) International Chess Federation
(d) Faculty of Dance and Education
- People celebrate World UFO Day on
(a) 24 June (b) 1 April
(c) 2 July (d) Both (a) and (c)

Answer Key

- | | | | | |
|---------|--------|--------|--------|--------|
| (p) 10. | (c) 6. | (q) 8. | (p) 7. | (q) 9. |
| (a) 5. | (c) 4. | (d) 3. | (b) 2. | (a) 1. |



Here are the nine shuffled words containing 3 sets of trio. The three letters of trio can be arranged in any sequence. Complete these words by finding 3 sets of trio.

S _ _ _ S
P _ _ _ HBLENDE
I _ _ _ RHALOGEN
SOLV _ _ _
VO _ _ _ METER
KI _ _ _ ICS
_ _ _ RATE
CATALY _ _ _
CRY _ _ _

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names will be published in next issue.



Unlock Your Knowledge!



1. The number of significant figures in 27 is _____.
2. Splitting of spectral lines into a number of thinner lines under the influence of electric field is called _____.
3. _____ is the process of forming amines using aminating agents, such as ammonia, primary and secondary amines.
4. _____ is the name for the element with atomic number 89 and is represented by the symbol Ac. It is a member of the actinide series.
5. Alkyl magnesium halides are known as _____ reagent.
6. _____ is the functional group containing a carbonyl group linked to a nitrogen atom.
7. The hybridisation of carbon in carboxylic group ($-\text{COOH}$) is _____.
8. _____ is an important family of proteins found in tissues like skin and blood vessels, and provides elasticity and flexibility.
9. Member of the same group of elements of the periodic table (e.g., iodine and chlorine) is called _____.
10. Positively charged ion with a valence of 2 is called _____ cation.
11. Dipole moment of NH_3 is _____ than dipole moment of NF_3 .
12. The shape of CH_3^- is _____.
13. $PV = \frac{1}{3} mnc^2$ is known as _____ equation.
14. The enthalpy of neutralization of weak acid -weak base is _____ than the neutralization of strong acid-strong base.
15. The system which can exchange both energy and mass with the surroundings is called _____ system.
16. When equilibrium constant (K) of a reaction is lesser than its reaction quotient (Q) the reaction proceeds more towards the _____ side.
17. When alcohol reacts with carboxylic acid, the reaction is called _____ reaction.
18. The solubility product of AgCl is _____ than the solubility product of AgBr .
19. When hydrochloric acid reacts with cobalt nitrate at room temperature, the initial colour of the solution becomes _____.
20. 31°C is the _____ temperature of carbon dioxide.

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names and answers will be published in next issue.

SOLUTIONS TO JUNE 2025 QUIZ CLUB

- | | |
|----------------------------|---------------------------------------|
| 1. Collagen | 12. Lead storage |
| 2. Weak acid | 13. Pseudo first |
| 3. Dry Ice | 14. Coagulation |
| 4. Osmotic | 15. Laughing (N_2O) |
| 5. Wilkinson's catalyst | 16. Eigen values |
| 6. <i>D</i> -penicillamine | 17. Flerovium |
| 7. Cheilosis | 18. Rhombic sulphur (S_8) |
| 8. Oxidoreductase | 19. Calorific |
| 9. Argon | 20. Carbonic acid and bicarbonate ion |
| 10. ICl_3 | |
| 11. Frenkel | |

Winners: Naveen Kumar, Anit Gaur

FOCUS

TOPIC

Bonding in Coordination Compounds

Detailed theory with High Definition images of the given topic is covered under this heading.

TERMS RELATED TO COORDINATION COMPOUNDS



Central metal atom : Metal atom to which ligands are attached.

Ligands : The donor atoms, molecules or anions which donate a pair of electrons to the metal atom or ion and form a coordinate bond.

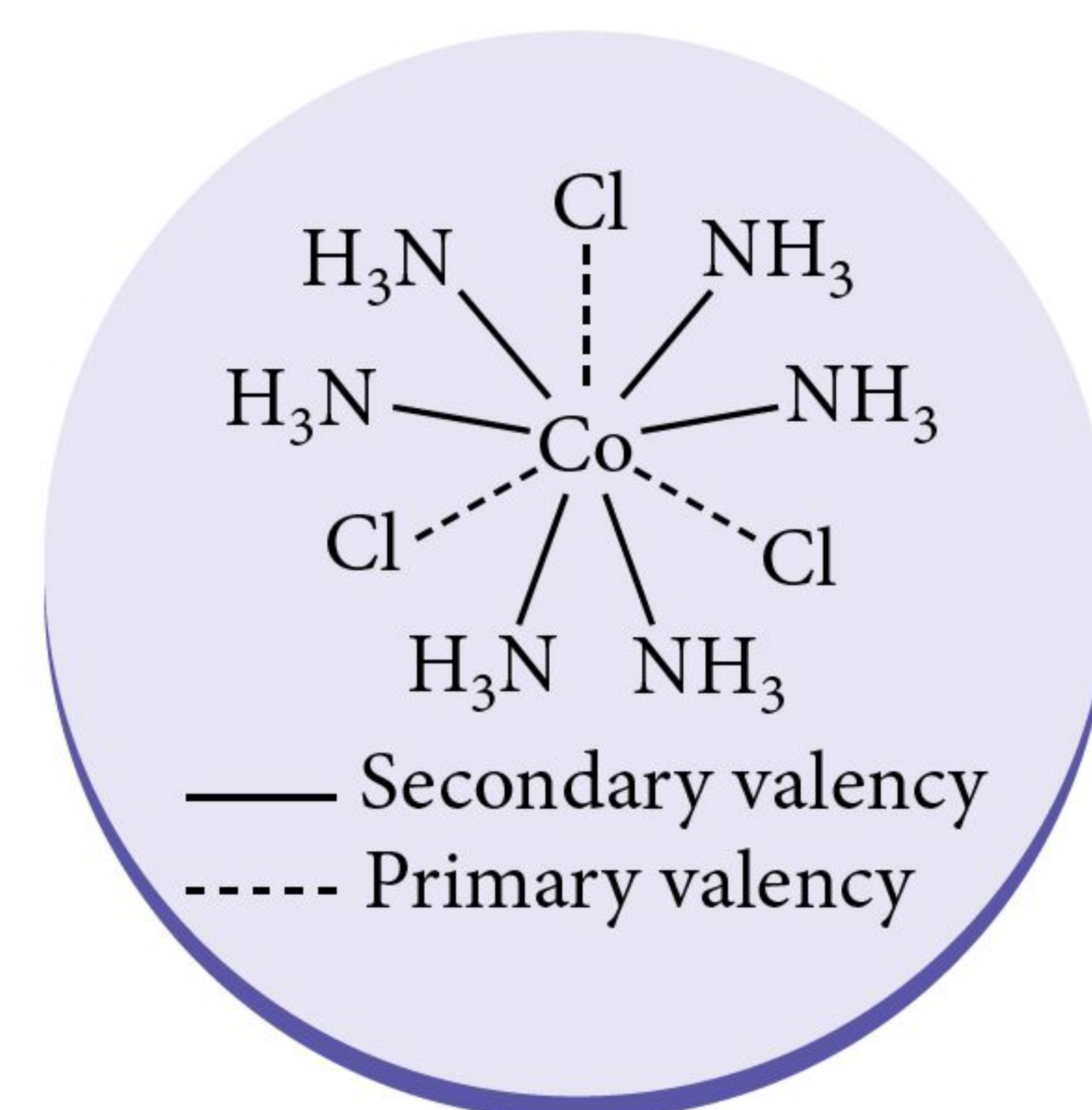
Counter ions : The ionizable groups written outside the bracket.

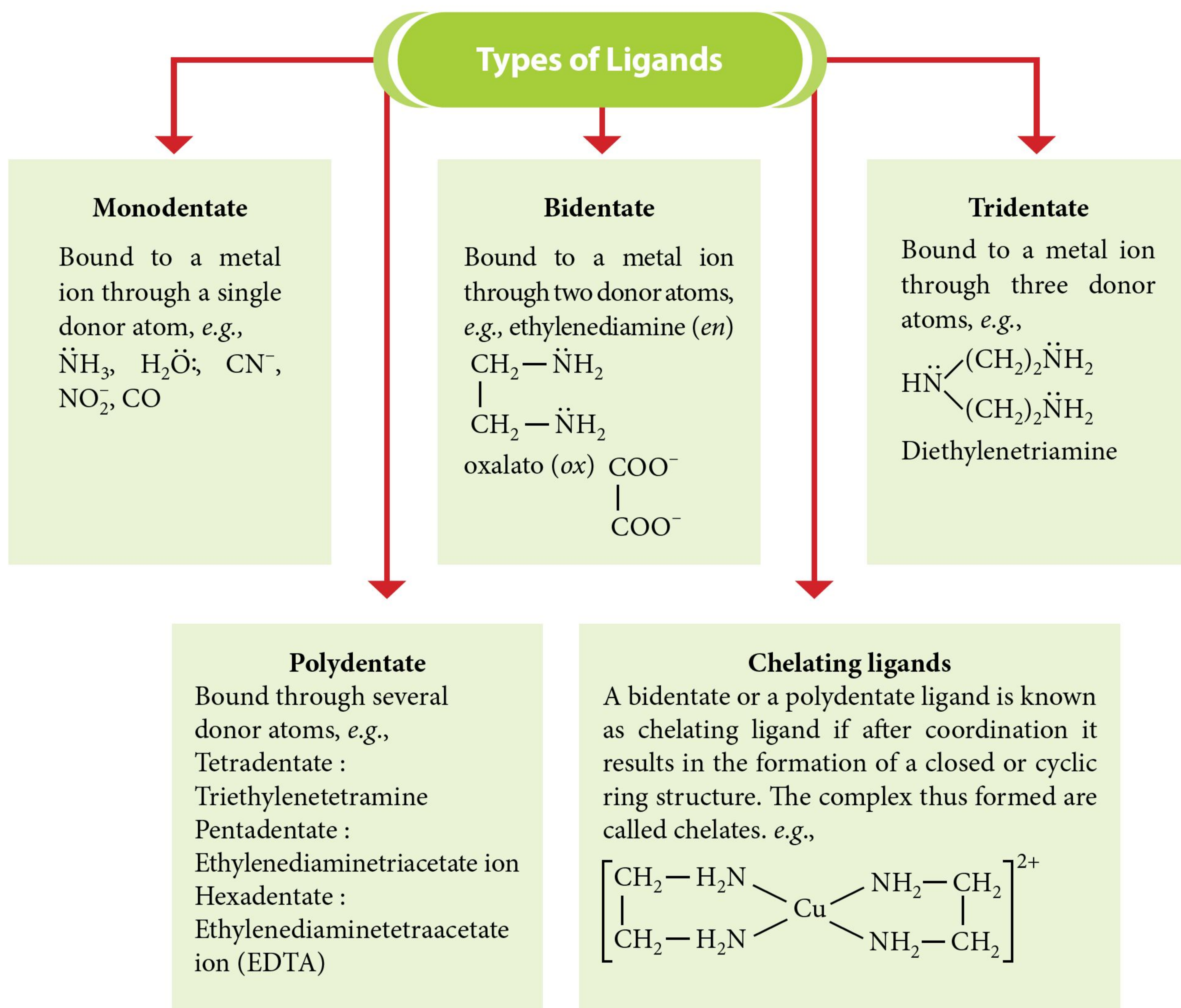
Coordination number : The total number of donor atoms or ligands attached to the central metal ion through coordinate bond.

Coordination sphere : Square bracket enclosing the central atom and the ligands directly attached to it.

WERNER'S THEORY

- ◆ Metal possesses two types of valencies, *i.e.*, primary valency (ionisable) and secondary valency (non-ionisable).
- ◆ Primary valency corresponds to the oxidation state of the central metal and secondary valency represents the coordination number of the metal.
- ◆ Primary valencies are satisfied by negative ions, while secondary valencies may be satisfied by neutral or negative ions.
- ◆ Negative ion can satisfy both primary and secondary valencies at the same time.





BONDING IN COORDINATION COMPOUNDS

Many approaches have been put forth to explain the nature of bonding in coordination compounds viz. valence bond theory (VBT), crystal field theory (CFT), ligand field theory (LFT) and molecular orbital theory (MOT). We shall focus our attention on VBT and CFT only.

VALENCE BOND THEORY (VBT)

- ◆ Main postulates of this theory are
 - The central metal ion makes available as many number of empty orbitals as its coordination number in compound formation.
 - Appropriate vacant orbitals of metal undergoes hybridisation to give a definite geometry such as square planar(dsp^2), tetrahedral (sp^3), octahedral(d^2sp^3), etc.
 - Empty hybrid orbital of metal overlap with filled orbital of ligands containing lone pair to form $M \leftarrow L$ coordinate bond.
- ◆ The d -orbitals participating in the process of hybridization in octahedral complexes may either be $(n-1)d^2sp^3$, inner or low spin complexes or nsp^3d^2 outer or high spin complexes.

Coordination Number	Type of Hybridisation	Geometry	Examples
2	sp	Linear	$[\text{Ag}(\text{NH}_3)_2]^+$, $[\text{Ag}(\text{CN})_2]^-$
3	sp^2	Trigonal planar	$[\text{HgI}_3]^-$
4	sp^3	Tetrahedral	$\text{Ni}(\text{CO})_4$, $[\text{NiX}_4]^{2-}$, $[\text{ZnCl}_4]^{2-}$, $[\text{CuX}_4]^{2-}$, where $X = \text{Cl}^-$, Br^- , I^-
	dsp^2	Square planar	$[\text{Ni}(\text{CN})_4]^{2-}$, $[\text{Cu}(\text{NH}_3)_4]^{2+}$, $[\text{Ni}(\text{NH}_3)_4]^{2+}$
5	dsp^3	Trigonal bipyramidal	$\text{Fe}(\text{CO})_5$, $[\text{CuCl}_5]^{3-}$
	sp^3d	Square pyramidal	$[\text{SbF}_5]^{2-}$
6	d^2sp^3	Octahedral (Inner orbital)	$[\text{Cr}(\text{NH}_3)_6]^{3+}$, $[\text{Fe}(\text{CN})_6]^{3-}$
	sp^3d^2	Octahedral (Outer orbital)	$[\text{FeF}_6]^{3-}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Ni}(\text{NH}_3)_6]^{2+}$

Differences between inner orbital and outer orbital complexes :

S.N.	Inner orbital octahedral complexes (Low spin complexes)	Outer orbital octahedral complexes (High spin complexes)
1.	The complexes are formed by strong field ligands and showing d^2sp^3 -hybridisation.	The complexes are formed by weak field ligands and showing sp^3d^2 -hybridisation.
2.	These complexes generally possess less number of unpaired electrons <i>i.e.</i> , they show either low or no magnetic moment.	These complexes generally possess greater number of unpaired electrons <i>i.e.</i> , they show high magnetic moment.
3.	These are less reactive <i>i.e.</i> , more stable. Substitution reactions are difficult to occur.	These are reactive <i>i.e.</i> , less stable. Substitution reactions are easy to occur.

Limitations of VBT

Although the VB theory explains the formation, structures and magnetic behaviour of coordination compounds to a large extent, it suffers from the following limitations :

- ◆ It involves a number of assumptions.
- ◆ It does not give quantitative interpretation of magnetic data.
- ◆ It does not explain the colour exhibited by coordination compounds.
- ◆ It does not distinguish between weak and strong ligands.

Crystal Field Theory

CFT is an electrostatic model. Due to the negative field of ligands the degeneracy of the metal ' d ' orbitals is lifted. That results in splitting of the ' d ' orbitals. The splitting pattern depends on the nature of the crystal field *i.e.*, octahedral or tetrahedral.

CONCEPT MAP

COORDINATION COMPOUNDS

NOMENCLATURE OF COORDINATION COMPOUNDS

Rules for nomenclature :

- Positive ion is named first followed by negative ion.
- Negative ligands are named by adding suffix - o.
- Positive ligands are named by adding suffix - ium.
- Neutral ligands are named as such without adding any suffix or prefix.
- Ligands are named in alphabetical order.
- Name of the ligands is written first followed by name of metal with its oxidation number mentioned in roman numerals in simple parenthesis.
- Number of the polysyllabic ligands *i.e.*, ligands which have numbers in their name, is indicated by prefixes bis, tris, tetrakis, etc.
- When both cation and anion are complex ions, the metal in negative complex is named by adding suffix -ate.

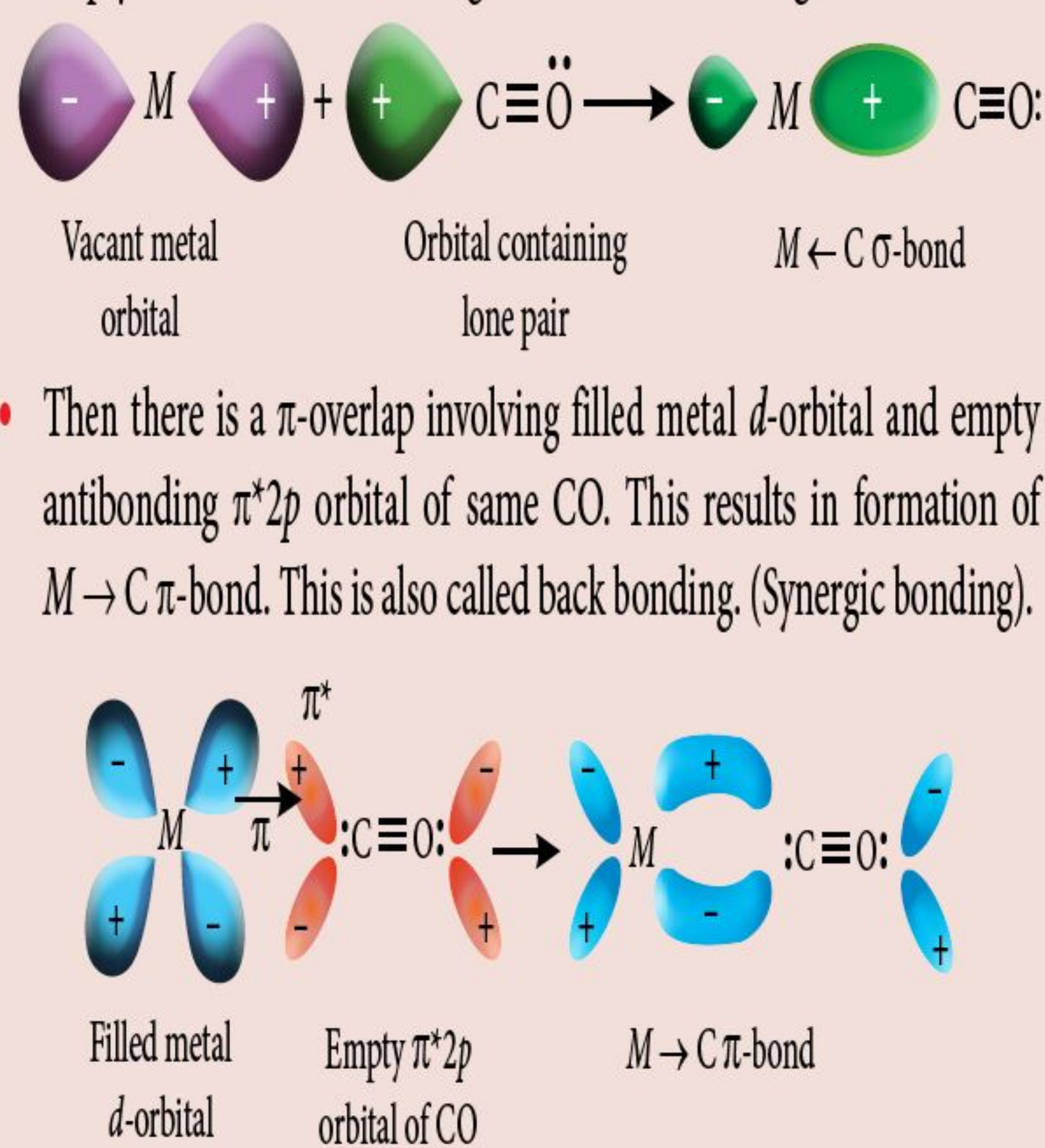
Ligand	Name in complexes	Ligand	Name in complexes
Azide (N_3^-)	Azido	Oxalate ($\text{C}_2\text{O}_4^{2-}$)	Oxalato
Bromide (Br^-)	Bromido	Oxide (O^{2-})	Oxo
Chloride (Cl^-)	Chlorido	Ammonia (NH_3)	Ammine
Cyanide (CN^-)	Cyano	Carbon monoxide (CO)	Carbonyl
Fluoride (F^-)	Fluorido	Ethylene-diamine (<i>en</i>)	Ethane-1,2-diamine
Hydroxide (OH^-)	Hydroxo	Pyridine ($\text{C}_5\text{H}_5\text{N}$)	Pyridine
Carbonate (CO_3^{2-})	Carbonato	Water (H_2O)	Aqua

Few examples illustrate the nomenclature :

- $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$ - Hexaammineplatinum(IV) chloride
- $[\text{Cu}(\text{en})_2]\text{SO}_4$ - bis(ethane-1,2-diamine)copper(II) sulphate
- $\text{K}_4[\text{Fe}(\text{CN})_6]$ - Potassium hexacyanoferrate(II)
- $[\text{Pt}(\text{NH}_3)_4\text{Cl}_2][\text{PtCl}_4]$ - Tetraamminedichlorido-platinum(IV) tetrachloridoplatinate(II)

BONDING IN METAL CARBONYLS

- Metal-carbon bond in metal carbonyls possesses both σ - and π -bond character. Its formation involves following steps:
- There is an overlap of filled bonding $\pi 2p$ orbital of CO with suitable empty metal d orbital resulting in the formation of sigma bond.
- Then there is a π -overlap involving filled metal d -orbital and empty antibonding $\pi^* 2p$ orbital of same CO. This results in formation of $M \rightarrow C \pi$ -bond. This is also called back bonding. (Synergic bonding).



ISOMERISM IN COORDINATION COMPOUNDS

Structural Isomerism

Ionisation Isomerism

- Isomerism arises in the compounds which have same molecular formula but give different ions in solution, *e.g.*, $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$, $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$.

Hydrate Isomerism

- Isomers having different number of H_2O as a ligand and as water of hydration.

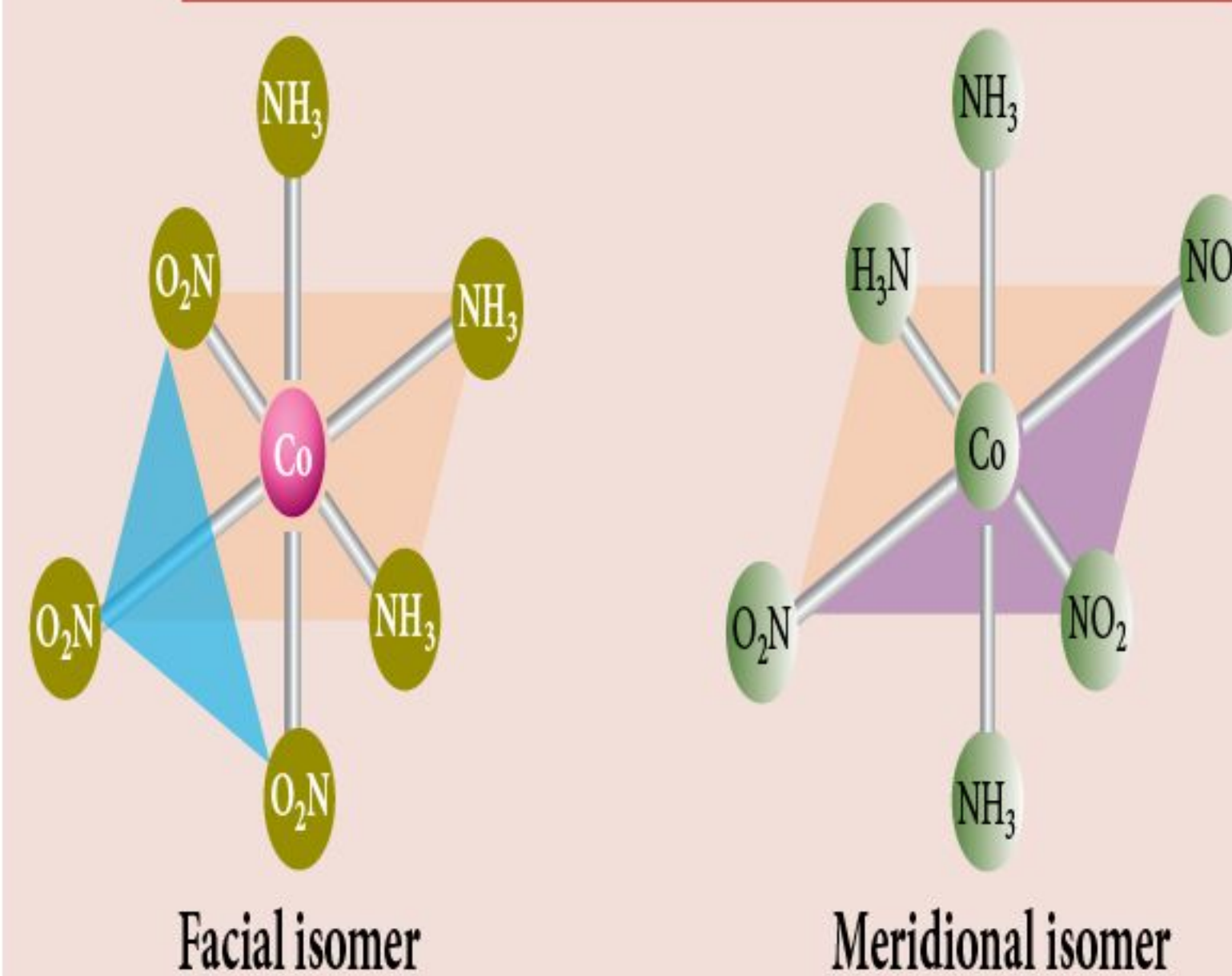
Linkage Isomerism

- Occurs in the complex compounds which contain ambidentate ligand. *e.g.*, $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$ or $[\text{Co}(\text{NH}_3)_5\text{ONO}]\text{Cl}_2$

Geometrical Isomerism

- If two identical ligands occupy adjacent positions $\Rightarrow$ *cis*
- If occupy opposite positions $\Rightarrow$ *trans*

Geometrical Isomerism in Octahedral Complexes



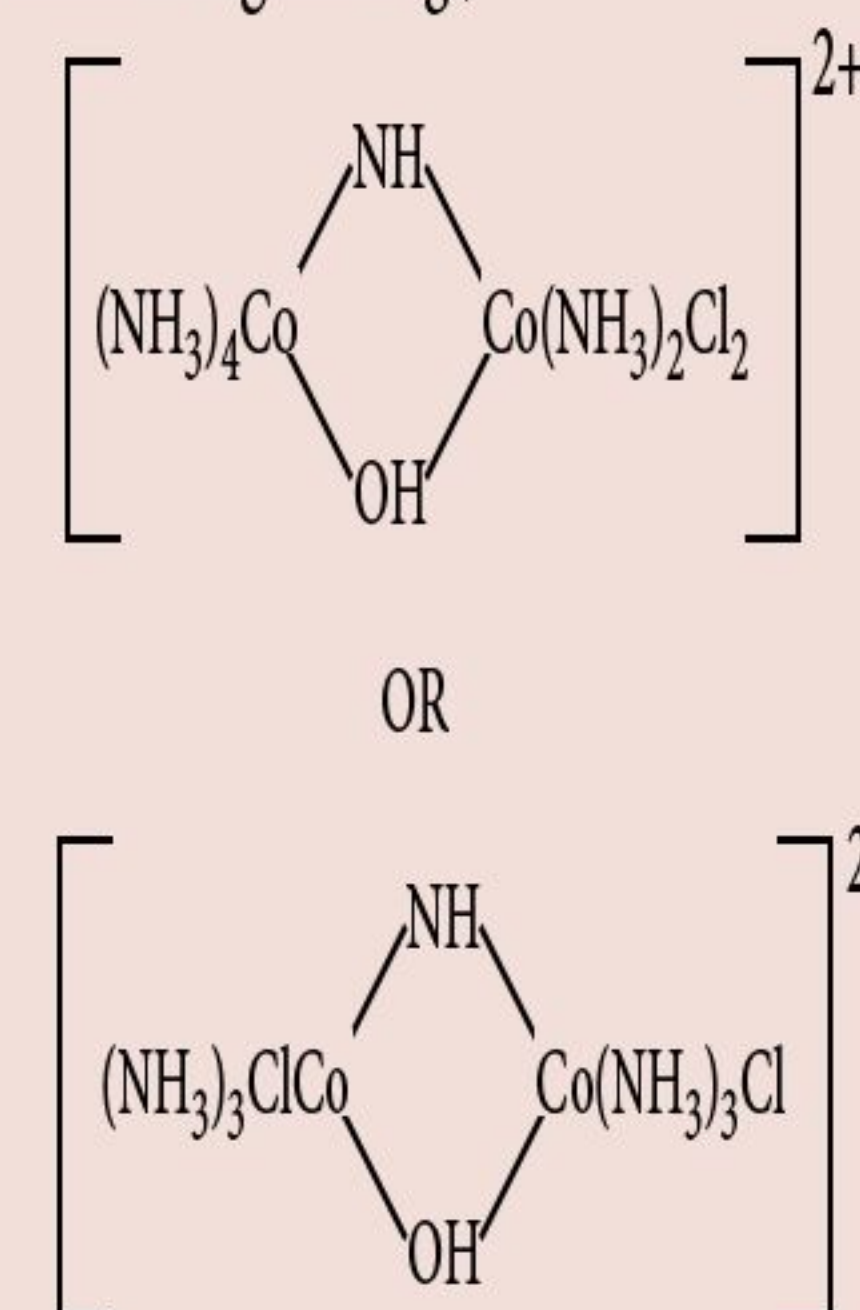
If all three similar groups occupy adjacent position at the corners of octahedral face then *fac*-isomer

If three similar groups present around meridian of octahedron then *mer*-isomer

Geometrical isomerism is not shown by tetrahedral complexes.

Coordination (position) Isomerism

- Exhibited by polynuclear complexes by interchanging the position of ligands. *e.g.*,



Polymerisation Isomerism

- Isomerism arises in the compounds which have same stoichiometric composition but different molecular composition. $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ and $[\text{Pt}(\text{NH}_3)_4][\text{PtCl}_4]$

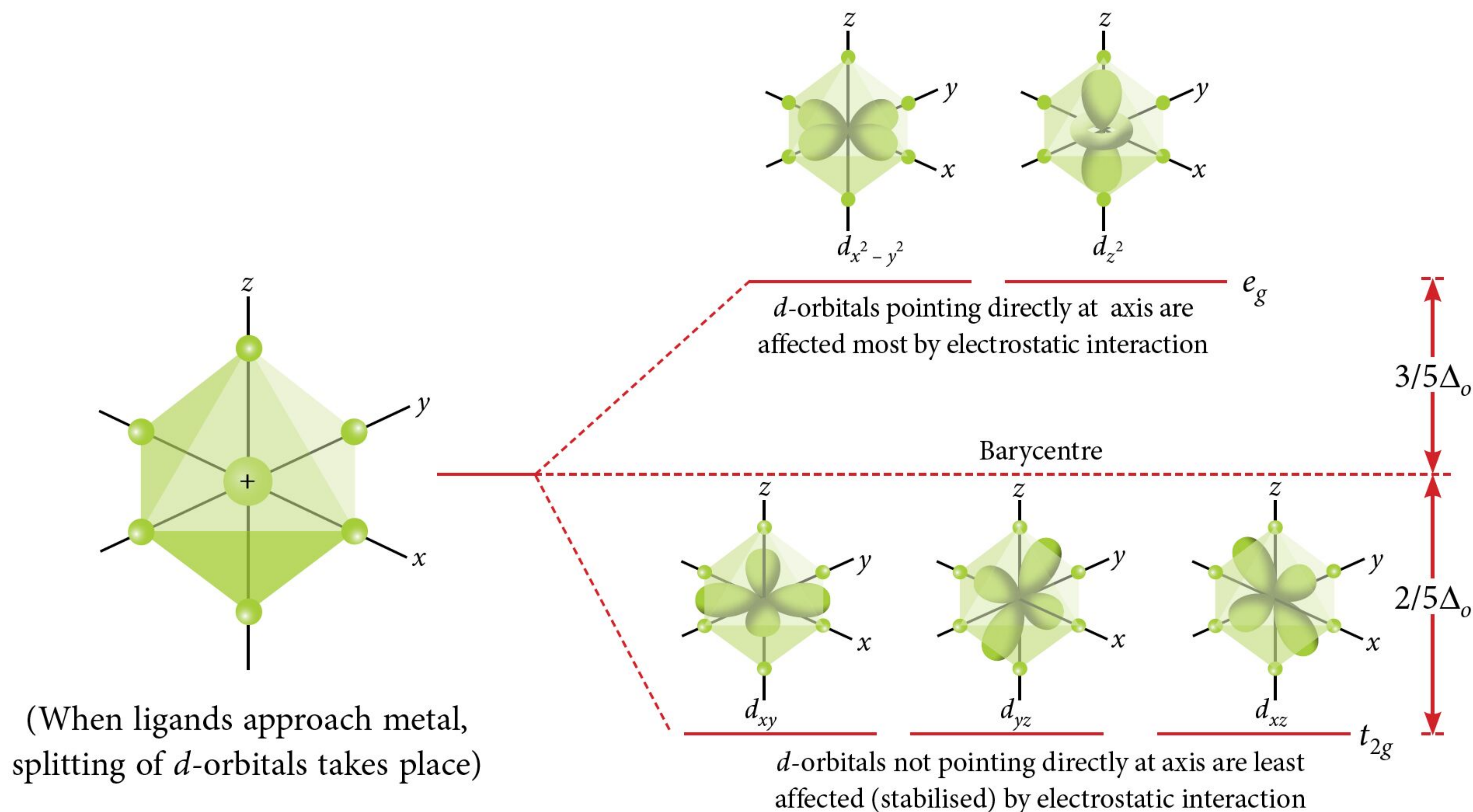
Coordination Isomerism

- Isomerism arises when both complex cation and complex anion are present. $[\text{Pt}(\text{NH}_3)_4][\text{CuCl}_4]$ and $[\text{PtCl}_4][\text{Cu}(\text{NH}_3)_4]$

Geometrical Isomerism in Square Planar Complexes

Type	Example	
	Cis-Isomer	Trans-Isomer
MA_2BC		
$\text{M}(\text{ab})_2$		
MABCD		

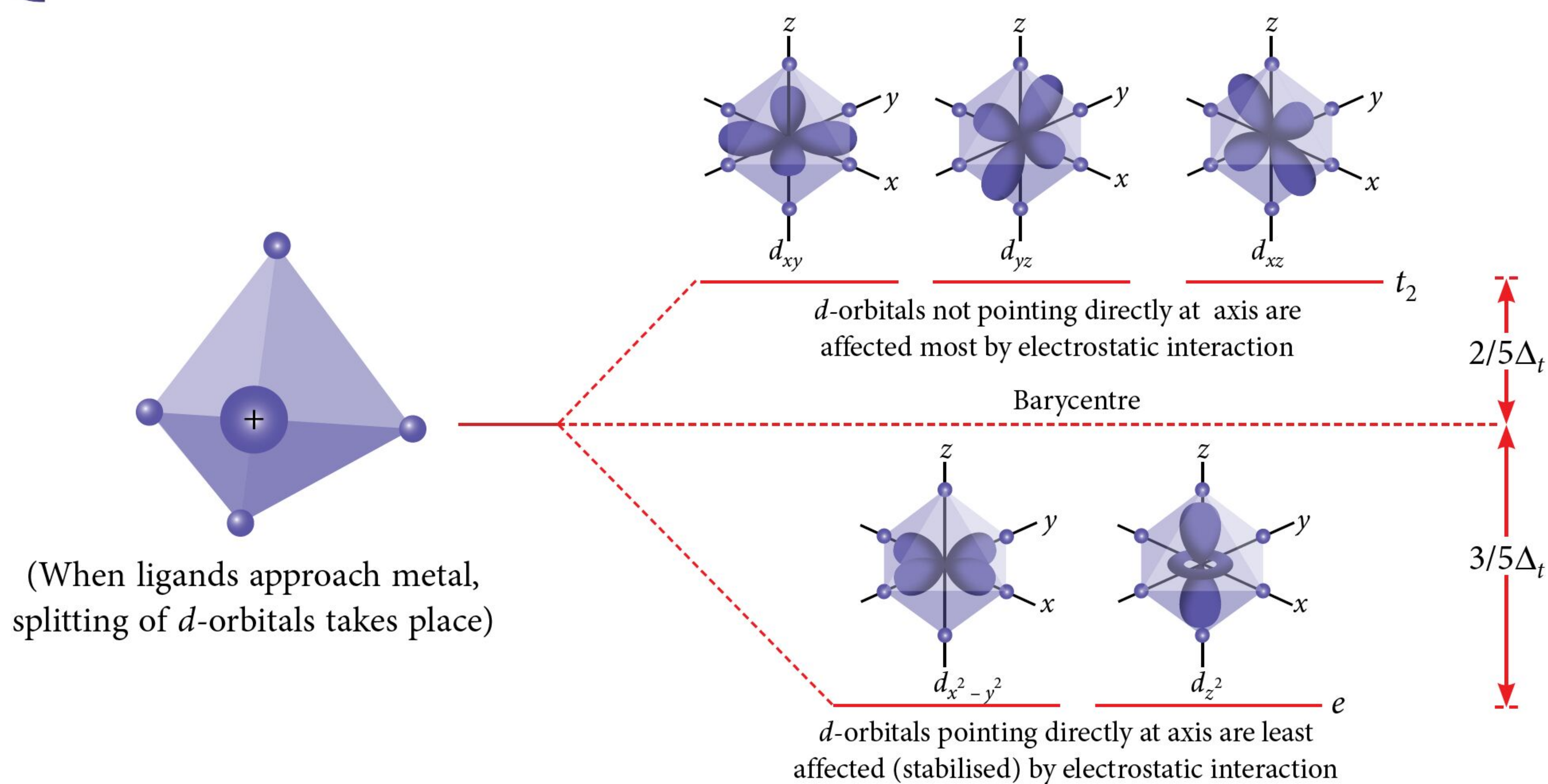
d-Orbitals and Ligands Interaction (Octahedral Complex)



All the six ligands are assumed to be positioned along the axis with the metal atom at the origin.

- ◆ If $\Delta_o < P$, where ' P ' is energy required for forced pairing of electrons then the electrons will remain unpaired and a high spin complex will be formed.
- If $\Delta_o > P$, then pairing of electrons will take place and a low spin complex will be formed.

d-Orbitals and Ligands Interaction (Tetrahedral Complex)



Spectrochemical Series

- The crystal field splitting (Δ) depends upon the field produced by the ligand and charge on the metal ion.
- Ligands are arranged in the order of increasing field strength called spectrochemical series.
- $\text{I}^- < \text{Br}^- < \text{SCN}^- < \text{Cl}^- < \text{S}^{2-} < \text{F}^- < \text{OH}^- < \text{C}_2\text{O}_4^{2-} < \text{H}_2\text{O} < \text{NCS}^- < \text{EDTA}^{4-} < \text{NH}_3 < \text{en} < \text{NO}_2^- < \text{CN}^- < \text{CO}$

Weak field
ligand

Increasing order of CFSE

Strong field
ligand

Calculation of CFSE

- In an octahedral complex, each electron occupying t_{2g} orbital results in lowering of energy by $-0.40 \Delta_o$ (or -4 Dq). Similarly, each electron occupying e_g orbital results in increase of energy by $+0.60 \Delta_o$ (or $+6 \text{ Dq}$). Thus, $\text{CFSE} = (-0.4x + 0.6y) \Delta_o$
where, x = number of electrons occupying t_{2g} orbitals and y = number of electrons occupying e_g orbitals.
Negative value of CFSE indicates net lowering in energy, i.e., gain in stability.

Calculation of CFSE Values for d^1 to d^{10} Configurations

Metal ion configuration	Low spin state (strong field ligand)	CFSE (Δ_o/Dq)	High spin state (weak field ligand)	CFSE (Δ_o/Dq)
d^1	$t_{2g}^1 e_g^0$	$-0.4 \times 1 = -0.4 \Delta_o$ or -4 Dq	$t_{2g}^1 e_g^0$	$-0.4 \times 1 = -0.4 \Delta_o$ or -4 Dq
d^2	$t_{2g}^2 e_g^0$	$-0.4 \times 2 = -0.8 \Delta_o$ or -8 Dq	$t_{2g}^2 e_g^0$	$-0.4 \times 2 = -0.8 \Delta_o$ or -8 Dq
d^3	$t_{2g}^3 e_g^0$	$-0.4 \times 3 = -1.2 \Delta_o$ or -12 Dq	$t_{2g}^3 e_g^0$	$-0.4 \times 3 = -1.2 \Delta_o$ or -12 Dq
d^4	$t_{2g}^4 e_g^0$	$-0.4 \times 4 = -1.6 \Delta_o$ or -16 Dq	$t_{2g}^3 e_g^1$	$-0.4 \times 3 + 0.6 = -0.6 \Delta_o$ or -6 Dq
d^5	$t_{2g}^5 e_g^0$	$-0.4 \times 5 = -2.0 \Delta_o$ or -20 Dq	$t_{2g}^3 e_g^2$	$-0.4 \times 3 + 2 \times 0.6 = 0.0 \Delta_o$ or 0 Dq
d^6	$t_{2g}^6 e_g^0$	$-0.4 \times 6 = -2.4 \Delta_o$ or -24 Dq	$t_{2g}^4 e_g^2$	$-0.4 \times 4 + 2 \times 0.6 = -0.4 \Delta_o$ or -4 Dq
d^7	$t_{2g}^6 e_g^1$	$-0.4 \times 6 + 0.6 = -1.8 \Delta_o$ or -18 Dq	$t_{2g}^5 e_g^2$	$-0.4 \times 5 + 2 \times 0.6 = -0.8 \Delta_o$ or -8 Dq
d^8	$t_{2g}^6 e_g^2$	$-0.4 \times 6 + 2 \times 0.6 = -1.2 \Delta_o$ or -12 Dq	$t_{2g}^6 e_g^2$	$-0.4 \times 6 + 2 \times 0.6 = -1.2 \Delta_o$ or -12 Dq
d^9	$t_{2g}^6 e_g^3$	$-0.4 \times 6 + 3 \times 0.6 = -0.6 \Delta_o$ or -6 Dq	$t_{2g}^6 e_g^3$	$-0.4 \times 6 + 3 \times 0.6 = -0.6 \Delta_o$ or -6 Dq
d^{10}	$t_{2g}^6 e_g^4$	$-0.4 \times 6 + 4 \times 0.6 = 0.0 \Delta_o$ or 0 Dq	$t_{2g}^6 e_g^4$	$-0.4 \times 6 + 4 \times 0.6 = 0.0 \Delta_o$ or 0 Dq

Similarly, for tetrahedral complex $\text{CFSE} = (-0.6x + 0.4y) \Delta_t$ also $\Delta_t = \frac{4}{9} \Delta_o$

Colour of Complexes

- ◆ The energy difference for the first transition series generally falls in the visible region. Absorption of one colour in the visible spectrum results in the ion having the complementary colour.
- ◆ The amount of d -orbital splitting depends on the ligands, thus different ligands have different splitting energies (Δ_o values) and different colours result.

Colour of the absorbed light	Range of wavelength (in Å) of the absorbed light	Range of frequency (in cm^{-1}) of the absorbed light	Colour of the transmitted light (Complementary colour of the absorbed light)
Violet (Highest energy)	4000 – 4500	25,000 – 22,222	Yellow Green
Blue	4500 – 4800	22,222 – 20,833	Yellow
Green Blue	4800 – 4900	20,833 – 20,408	Orange
Blue Green	4900 – 5000	20,408 – 20,000	Red
Green	5000 – 5600	20,000 – 17,857	Violet (almost purple)
Yellow Green	5600 – 5750	17,857 – 17,391	Violet
Yellow	5750 – 5900	17,391 – 16,949	Blue
Orange	5900 – 6250	16,949 – 16,000	Green Blue
Red (Lowest energy)	6250 – 7500	16,000 – 13,333	Blue Green

STABILITY OF COORDINATION COMPOUNDS

Stability depends on

Charge on the central metal ion (oxidation state) :
Greater the charge on central metal ion, more is the stability.

Basic nature of ligand :
More is the basic strength of ligand, more will be the stability of complex.

Presence of chelate rings:
Formation of chelate ring increases the stability of complex.

Size of the metal ion :
Smaller the size of metal ion, more is the stability.

Electronegativity and polarising power of the central metal ion : More is the electronegativity and polarising power of the metal ion, more stable is the complex.



CLASS-XI

CBSE

Warm-up!

Chapterwise practice questions for CBSE Exams as per the latest pattern and syllabus by CBSE for the academic session 2025-26.

Series-2

Structure of Atom

General Instructions : Read the following instructions carefully and follow them :

- (i) This question paper contains 33 questions. All questions are compulsory.
- (ii) Question paper is divided into five sections – Section A, B, C, D and E.
- (iii) Section A – questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.
- (iv) Section B – questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.
- (v) Section C – questions number 22 to 28 are short answer type questions. Each question carries 3 marks.
- (vi) Section D – questions number 29 to 30 are case-based questions. Each question carries 4 marks.
- (vii) Section E – questions number 31 to 33 are long answer type questions. Each question carries 5 marks.
- (viii) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the sections except section A.
- (ix) Kindly note that there is a separate question paper for Visually Impaired candidates.
- (x) Use of calculators is not allowed.

Time Allowed : 3 hours

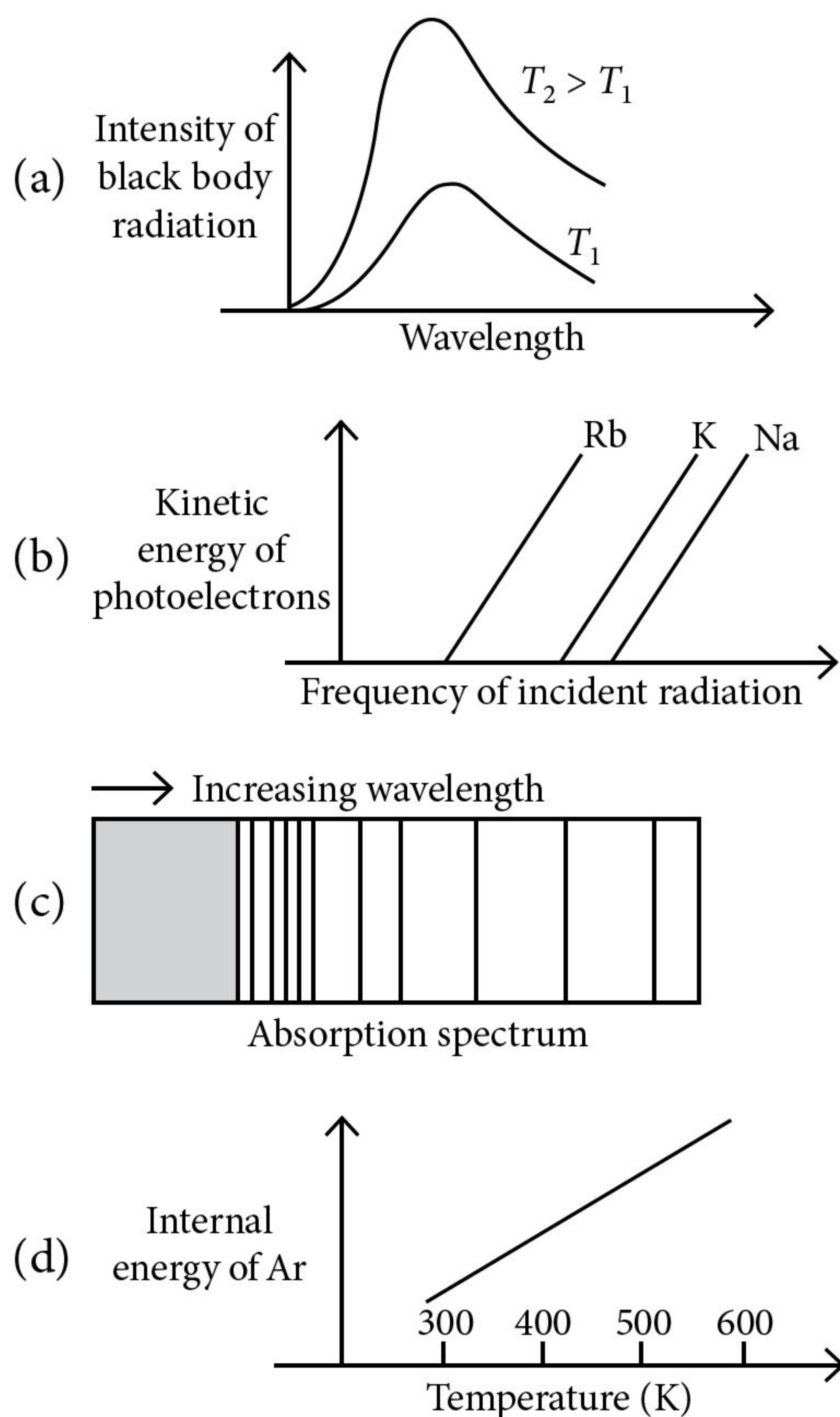
Maximum Marks : 70

SECTION-A

Question No. 1 to 16 are multiple choice type questions carrying 1 mark each.

1. An ion with mass number 56 contains three units of positive charge and 30.4% more neutrons than electrons. The ion is
(a) ${}^{56}_{28}\text{Ni}^{3+}$ (b) ${}^{56}_{26}\text{Fe}^{3+}$
(c) ${}^{56}_{27}\text{Co}^{3+}$ (d) ${}^{56}_{24}\text{Cr}^{3+}$
2. The ratio of specific charge of a proton and an α -particle is
(a) 2 : 1 (b) 1 : 2
(c) 1 : 4 (d) 1 : 1
3. The electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ represents a
(a) metal atom
(b) non-metal atom
(c) non-metallic anion
(d) metallic cation.
4. The Bohr's orbit radius for the hydrogen atom ($n = 1$) is approximately $0.530 \text{ \AA}$. The radius for the first excited state ($n = 2$) orbit is
(a) $4.77 \text{ \AA}$ (b) $1.06 \text{ \AA}$ (c) $0.13 \text{ \AA}$ (d) $2.12 \text{ \AA}$.
5. The de Broglie wavelength of a particle is
(a) proportional to its mass
(b) proportional to its velocity
(c) inversely proportional to its momentum
(d) proportional to its total energy.
6. Calculate the number of photons of light of wavelength $3960 \text{ \AA}$ necessary to provide 1 J of energy.
(a) 2×10^{20} (b) 2×10^{16}
(c) 2×10^{15} (d) 2×10^{18}
7. Maximum number of photons emitted by a bulb capable of producing monochromatic light of wavelength 550 nm is _____, if 100 V and 1 A is supplied for one hour.
(a) 1×10^{24} (b) 5×10^{24}
(c) 1×10^{23} (d) 5×10^{23}

8. The figure that is not a direct manifestation of the quantum nature of atom is



9. Which of the following observations was not correct during Rutherford's scattering experiment?

- (a) Most of the α -particles passed through the gold foil undeflected.
 (b) A small fraction of the α -particles was deflected by small angles.
 (c) A large number of the α -particles bounced back.
 (d) Very few α -particles (~ 1 in 20,000) bounced back.

10. Energy associated with the first orbit of He^+ is

- (a) $8.72 \times 10^{-18} \text{ J}$ (b) $0.872 \times 10^{-18} \text{ J}$
 (c) $-0.872 \times 10^{-18} \text{ J}$ (d) $-8.72 \times 10^{-18} \text{ J}$

11. If the de Broglie wavelength of a particle of mass m is 100 times its velocity, then its value in terms of its mass (m) and Planck's constant (h) is

- (a) $\frac{1}{10} \sqrt{\frac{m}{h}}$ (b) $10 \sqrt{\frac{h}{m}}$
 (c) $\frac{1}{10} \sqrt{\frac{h}{m}}$ (d) $10 \sqrt{\frac{m}{h}}$

12. Which of the following sets of quantum numbers represents the highest energy of an atom?

- (a) $n = 3, l = 0, m = 0, s = +1/2$
 (b) $n = 3, l = 1, m = 1, s = +1/2$
 (c) $n = 3, l = 2, m = 1, s = +1/2$
 (d) $n = 4, l = 0, m = 0, s = +1/2$

For questions number 13 to 16, two statements are given- one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

- (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
 (b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
 (c) Assertion (A) is true, but Reason (R) is false.
 (d) Assertion (A) is false, but Reason (R) is true.

13. **Assertion (A)** : It is impossible to determine the exact position and exact momentum of an electron simultaneously.

Reason (R) : The path of an electron in an atom is clearly defined.

14. **Assertion (A)** : For Balmer series of hydrogen spectrum, the value $n_1 = 2$ and $n_2 = 3, 4, 5$.

Reason (R) : The value of n for a line in Balmer series of hydrogen spectrum having the highest wavelength is 4 and 6.

15. **Assertion (A)** : The quantum numbers $n = 4, l = 3, m = +1$ and $s = +\frac{1}{2}$ represent $4f$ orbital.

Reason (R) : For $4f$ orbital, $n = 4$ and $l = 2$.

16. **Assertion (A)** : Orbitals with the same value of l and m_l have the same angular wave function.

Reason (R) : Angular wave function does not depend upon the n .

SECTION-B

17. (a) The number of electrons, protons and neutrons in a species are equal to 18, 16 and 16 respectively. Assign the proper symbol to the species.

- (b) How many nucleons are present in the atom $^{254}_{102}\text{X}$? How many of these may be considered as neutrons?

18. List three differences between cathode rays and canal rays.
19. The threshold energy for photoelectric emission of electrons from a metal is 4.53×10^{-14} J. If light of 4000 Å wavelength is used, will the electrons be ejected or not?
20. (A) A bulb emits light of wavelength 4500 Å. The bulb is rated as 150 watt and 8% of the energy is emitted as light. How many photons are emitted by the bulb per second?

OR

- (B) Calculate the wave number and frequency of radiation having wavelength 4000 Å.
21. The two extra-nuclear electrons in the 1s orbital of helium have antiparallel spins ($\uparrow \downarrow$). Why do they not have parallel spins ($\uparrow \uparrow$)?

SECTION-C

22. Oxygen has three isotopes ^{16}O , ^{17}O and ^{18}O and carbon has two ^{12}C and ^{13}C . How many CO_2 molecules are possible from these isotopes and also report their molecular masses?
23. (A) In each of the following pairs of salts, which one is more stable and why?
- Ferrous and ferric salts
 - Cuprous and cupric salts

OR

- (B) If the energy of an electron in 3rd Bohr orbit is $-E$, what is the energy of the electron in :
- 1st Bohr orbit
 - 2nd Bohr orbit?
24. What is photoelectric effect? What is the effect of frequency and intensity on photoelectric effect?
25. Why was a change in the Bohr model of atom required? Due to which important development(s), concept of movement of an electron in an orbit was replaced by the concept of probability of finding electron in an orbital? What is the name given to the changed model of atom?
26. A photon of wavelength 4×10^{-7} m strikes on metal surface, the work function of the metal being 2.13 eV. Calculate :
- the energy of the photon (eV)
 - the kinetic energy of the emission
 - the velocity of the photoelectron
(1 eV = 1.602×10^{-19} J)

27. (a) State Heisenberg's uncertainty principle.
(b) A microscope using suitable photons is employed to locate an electron in an atom within distance of 0.1 Å. What is the uncertainty involved in the measurement of its velocity?
28. (a) Out of 2s and 2p which has higher energy?
(b) State Hund's rule.
(c) Draw the shape of $d_{x^2-y^2}$.

SECTION-D

The following questions are case based questions. Read the passage carefully and answer the questions that follow.

29. As a result of bombardment experiments with the foils of gold using alpha-particles as projectiles, Rutherford concluded that an atom consists of positively charged nucleus with electrons revolving around it. Calculations by Rutherford showed that the volume occupied by the nucleus is negligibly small as compared to the total volume of the atom. The radius of the atom is about 10^{-10} m, while that of nucleus is 10^{-15} m.

Answer the following questions :

- Write two drawbacks of Rutherford's model of atom.
- From what observation do you derive the inference that most of the space inside the atom is empty?

OR

- What is the approximate ratio of diameter of atom to the diameter of nucleus?
 - Write the formula for α -particles used in the Rutherford experiment.
30. Pauli's exclusion principle states that no two electrons in an atom can be in the same state or configuration at the same time. An orbital occupied by a pair of electrons of opposite spin is filled, no more electrons may enter it until one of the pair vacates the orbital.
- The Aufbau principle (also Aufbau rule or building-up principle), is used to determine the electron configuration of an atom, molecule or ion. According to the principle, electrons fill orbitals starting at the lowest available energy states before filling higher states.
- Hund's rule of maximum multiplicity is a principle of atomic chemistry which states that a greater total spin state usually makes the resulting atom

more stable, most commonly manifested in a lower energy state, because it forces the unpaired electrons to reside in different spatial orbitals. Also, the electrons filling a subshell will have parallel spin before the shell starts filling up with the opposite spin electrons (after the first orbital gains a second electron).

Answer the following questions :

- (a) What is the spin angular momentum value for unpaired electron in sodium (Atomic No. = 11)?
- (b) How many electrons have the quantum numbers $n = 4$, $l = 0$ and $s = -1/2$ in Zn^{2+} ion?
- (c) "When two electrons are placed in two degenerate orbitals of the atom, the energy is lower if their spin is parallel". This statement is based on which rule/principle?

OR

- (c) State Pauli's exclusion principle.

SECTION-E

31. (A) (a) The radius of first Bohr orbit of hydrogen atom is $0.529 \text{ \AA}$. Calculate the radii of:
- (i) the third orbit of He^+ ion and
 - (ii) the second orbit of Li^{2+} ion.

- (b) Using s , p , d notations, describe the orbital with the following quantum numbers :
- (i) $n = 3$, $l = 1$ (ii) $n = 1$, $l = 0$

OR

- (B) (a) Write the orbital electronic configuration and number of unpaired electrons in Cr^+ .
- (b) Why is there no $2d$ or $3f$ orbital?
- (c) How many maximum electrons will be present in the subshells having m_s value $+1/2$ for $n = 5$?
32. (A) (a) Neon gas is generally used in sign boards. If emitted strongly at 616 nm , calculate :
- (i) frequency of emission
 - (ii) distance travelled by this radiation in 30 s
 - (iii) energy of quanta.
- (b) To which orbit the electron in the hydrogen atom will jump on absorbing 12.1 eV of energy?

OR

- (B) (a) Differentiate between orbit and orbital.
- (b) The subshell that comes after f is called the g -subshell.

- (i) How many g -orbitals are present in this sub-shell?
- (ii) In which principal electronic shell would the g -subshell first occur?

33. (A) (a) What is meant by dual nature of light? Calculate the wavelength (in $\text{\AA}$) associated with an electron travelling at a speed of $2.19 \times 10^6 \text{ m/s}$.

- (b) Electromagnetic radiation of wavelength 242 nm is just sufficient to ionise the sodium atom. Calculate the ionisation energy of sodium in kJ mol^{-1} .

OR

- (B) (a) A metal surface of threshold frequency $5.3 \times 10^{14} \text{ s}^{-1}$ is exposed to a photon of radiation having energy $3.5 \times 10^{-19} \text{ J}$. Will it exhibit photoelectric effect?

- (b) Point out the angular momentum of an electron in :
- (i) $4s$ -orbital, (ii) $3p$ -orbital, (iii) 4^{th} orbit.

SOLUTIONS

1. (b): Let no. of electrons in the ion $M^{3+} = x$

$$\therefore \text{No. of neutrons} = x + \frac{30.4x}{100} = 1.304x$$

$$\text{No. of electrons in the neutral atom} = x + 3$$

$$\therefore \text{No. of protons} = x + 3$$

$$\text{Mass no.} = \text{No. of protons} + \text{No. of neutrons}$$

$$56 = x + 3 + 1.304x \Rightarrow 2.304x = 53 \Rightarrow x = 23$$

$$\text{No. of protons} = x + 3 = 23 + 3 = 26$$

$$\text{Hence, the ion is } {}_{26}^{56}\text{Fe}^{3+}.$$

2. (b): Proton $\rightarrow \text{H}^+$, α -particle $\rightarrow \text{He}^{2+}$
Specific charge ratio = $1 : 2$

3. (d): The electronic configuration of Cu is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$

$$\text{Cu}^{2+} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$$

Hence, the given electronic configuration is of a metallic cation

4. (d): For n^{th} orbit of 'H' atom, $r_n = n^2 \times r_1$
 $\Rightarrow$ Radius of 2^{nd} Bohr's orbit,
 $r_2 = 4 \times r_1 = 4 \times 0.530 = 2.12 \text{ \AA}$

5. (c): The de Broglie wavelength (λ) of a particle is inversely proportional to its momentum (p).

$$\text{i.e., } \lambda \propto \frac{1}{p}$$

6. (d): Applying, $E = n \frac{hc}{\lambda}$

$$E = 1 \text{ J}, h = 6.6 \times 10^{-34} \text{ J s}, c = 3 \times 10^8 \text{ m s}^{-1}$$

$$\lambda = 3960 \text{ Å} = 3960 \times 10^{-10} \text{ m}$$

$$n = \frac{1 \times 3960 \times 10^{-10}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 2 \times 10^{18}$$

$$\begin{aligned} 7. (a): \text{Energy of one photon} &= \frac{hc}{\lambda} \\ &= \frac{6.6 \times 10^{-34} \times 3.0 \times 10^8}{550 \times 10^{-9}} = 3.6 \times 10^{-19} \text{ J} \end{aligned}$$

$$\begin{aligned} \text{Energy absorbed per second by bulb} &= 100 \times 1 \times 3600 \\ (\because \text{Energy} &= V \times I \times t) \end{aligned}$$

Let n photons be evolved per second.

$$n \times 3.6 \times 10^{-19} = 100 \times 3600$$

$$n = \frac{100 \times 3600}{3.6 \times 10^{-19}} = 1 \times 10^{24}$$

8. (d): The direct manifestations of the quantum nature of atom are (i) the emission of radiations from hot bodies (black-body radiation) (ii) ejection of electrons from metal surface when radiation strikes it (photoelectric effect) (iii) absorption spectrum.

9. (c): Only a few α -particles (~ 1 in 20,000) bounced back.

10. (d): For H-like particles,

$$\begin{aligned} E_n &= \frac{-21.78 \times 10^{-19}}{n^2} Z^2 \text{ J} = \frac{-21.78 \times 10^{-19}}{1^2} \times (2)^2 \\ &= -8.712 \times 10^{-18} \text{ J} \end{aligned}$$

11. (b): Let wavelength of particle be x .

$$\text{So, velocity} = \frac{x}{100} \text{ and } \lambda = \frac{h}{mv}$$

$$x = \frac{h \times 100}{m \times x}, x^2 = 100 \frac{h}{m} \text{ or } x = 10 \sqrt{\frac{h}{m}}$$

12. (c): $n = 3, l = 0$ represents 3s orbital.

$n = 3, l = 1$ represents 3p orbital.

$n = 3, l = 2$ represents 3d orbital.

$n = 4, l = 0$ represents 4s orbital.

The order of increasing energy of the orbitals is $3s < 3p < 4s < 3d$.

13. (c): Path of an electron in an atom is not clearly defined. Electron is present in a region which is called orbital.

14. (c)

15. (c): For 4f orbital, $n = 4$ and $l = 3$ while $n = 4$ and $l = 2$ represents 4d orbital.

16. (b)

17. (a) The atomic number is equal to number of protons = 16. Thus, the element is sulphur (S).

Mass number = number of protons + number of neutrons = 16 + 16 = 32

Species is not neutral as the number of protons is not equal to electrons. It is anion (negatively charged) with charge equal to excess electrons = 18 - 16 = 2

Thus, the symbol is ${}^{32}_{16}\text{S}^{2-}$

(b) Nucleons = neutrons + protons = 254

Neutrons = nucleons - protons = 254 - 102 = 152

18.

	Cathode Rays	Canal Rays
1.	Cathode rays consist of negatively charged particles.	These rays consist of positively charged particles.
2.	The $\frac{e}{m}$ of the particles is independent of the gas and has a definite value.	The $\frac{e}{m}$ of the particles depends on the nature of the gas and is variable.
3.	They have a definite mass.	Mass depends on ions and is variable.

19. Electrons will be ejected only if the energy of incident light is greater than the threshold energy.

$$\begin{aligned} \text{Energy of the incident light} &= h\nu = h \frac{c}{\lambda} \\ &= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{4000 \times 10^{-10}} \text{ J} \\ &= 4.97 \times 10^{-19} \text{ J} \end{aligned}$$

As the energy of the incident light is less than the threshold energy therefore electrons will not be ejected.

MONTHLY TEST DRIVE CLASS XII

ANSWER

KEY

- | | | | | |
|-----------|---------------|-------------|---------|-----------|
| 1. (c) | 2. (c) | 3. (a) | 4. (b) | 5. (a) |
| 6. (c) | 7. (a) | 8. (a) | 9. (b) | 10. (b) |
| 11. (a) | 12. (d) | 13. (c) | 14. (a) | 15. (a) |
| 16. (c) | 17. (a) | 18. (c) | 19. (b) | 20. (a,d) |
| 21. (b,d) | 22. (a,b,c,d) | 23. (a,b,d) | 24. (5) | 25. (106) |
| 26. (5) | 27. (c) | 28. (d) | 29. (d) | 30. (d) |

20. (A) Power = Energy per second

150 watt = 150 J per second

$$\therefore E = 150 \text{ J}$$

$$\text{Energy emitted as light} = \frac{150 \times 8}{100} = 12 \text{ J}$$

$$\text{Radiant energy} = \frac{nhc}{\lambda}$$

$$n = \frac{12 \times 4500 \times 10^{-10}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 2.727 \times 10^{19} \text{ photons}$$

OR

(B) $\lambda = 4000 \text{ \AA} = 4000 \times 10^{-10} \text{ m} = 4 \times 10^{-7} \text{ m}$

$$\text{Wave number, } \bar{\nu} = \frac{1}{\lambda} = \frac{1}{4 \times 10^{-7} \text{ m}} = 2.5 \times 10^6 \text{ m}^{-1}$$

$$\text{Frequency, } \nu = \frac{c}{\lambda} = c \bar{\nu} = 3 \times 10^8 \times 2.5 \times 10^6 \\ = 7.5 \times 10^{14} \text{ Hz}$$

21. If they had parallel spins, the repulsion will increase. As a result, energy will increase and the stability will decrease.

22. Total number of CO_2 molecules possible = 12

From ^{12}C



Similarly, six molecules will be obtained from ^{13}C .

23. (A) (i) Electronic configuration of Fe atom ($Z = 26$)

$$= 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$$

Electronic configuration of Fe^{2+} ion = $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

Electronic configuration of Fe^{3+} ion = $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

As half-filled $3d^5$ configuration is more stable, therefore, ferric salts are more stable than ferrous salts.

(ii) Electronic configuration of Cu atom ($Z = 29$)

$$= 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$$

$\therefore$ Electronic configuration Cu^+ ion = $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

Electronic configuration Cu^{2+} ion = $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$

Although Cu^+ has fully-filled d -orbital, yet cuprous salts are less stable. This is because the nuclear charge is not sufficient enough to hold 18 electrons of Cu^+ ion present in the outermost shell.

OR

(B) We know, $E_n \propto \frac{1}{n^2}$

$$\therefore E_3 \propto \frac{1}{3^2}, \text{ i.e., } E_3 \propto \frac{1}{9}, E_2 \propto \frac{1}{2^2}, \text{ i.e., } E_2 \propto \frac{1}{4} \text{ and}$$

$$E_1 = \frac{1}{1^2}$$

$$\therefore \frac{E_3}{E_1} = \frac{1}{9} \text{ or } E_1 = 9E_3 = -9E \quad (\because E_3 = -E)$$

$$\frac{E_3}{E_2} = \frac{4}{9} \text{ or } E_2 = \frac{9}{4}E_3 = -\frac{9}{4}E = -2.25E$$

24. Photoelectric effect is defined as the emission of electrons when light is struck on a metal surface. Electrons emitted in this manner are called photoelectrons.

The intensity of incident light affects the number of emitted electrons while the frequency of the light determines the maximum kinetic energy of the ejected electrons.

25. Bohr's model postulated that electrons move along fixed circular paths which was contradicted by Heisenberg's uncertainty principle and de Broglie's concept of dual nature of electron. The concept of movement of electron in an orbit was replaced by concept of probability due to Heisenberg's uncertainty principle. The changed model of atom is called 'wave mechanical model of atom'.

26. (a) Energy of the photon (E) = $h\nu = \frac{hc}{\lambda}$

$$= \frac{(6.626 \times 10^{-34} \text{ J s}) \times (3 \times 10^8 \text{ m s}^{-1})}{4 \times 10^{-7} \text{ m}}$$

$$= 4.97 \times 10^{-19} \text{ J} = \frac{4.97 \times 10^{-19}}{1.602 \times 10^{-19}} \text{ eV} = 3.10 \text{ eV}$$

(b) Kinetic energy of emission $\left(\frac{1}{2}mv^2\right)$

$$= h\nu - h\nu_0 = 3.10 - 2.13 = 0.97 \text{ eV}$$

(c) $\frac{1}{2}mv^2 = 0.97 \text{ eV} = 0.97 \times 1.602 \times 10^{-19} \text{ J}$

$$\text{i.e., } \frac{1}{2} \times (9.11 \times 10^{-31} \text{ kg}) \times v^2 = 0.97 \times 1.602 \times 10^{-19} \text{ J}$$

$$\text{or, } v^2 = 0.341 \times 10^{12} = 34.1 \times 10^{10}$$

$$\text{or } v = 5.84 \times 10^5 \text{ m s}^{-1}$$

27. (a) Heisenberg's uncertainty principle states that it is impossible to determine simultaneously the exact position and exact momentum (or velocity) of an electron.

$$\text{Mathematically, } \Delta x \times \Delta p \geq \frac{h}{4\pi}$$

(b) $\Delta x \Delta p = \frac{h}{4\pi}$ or $\Delta x m \Delta v = \frac{h}{4\pi}$

$$\Delta v = \frac{h}{4\pi(\Delta x)m}$$

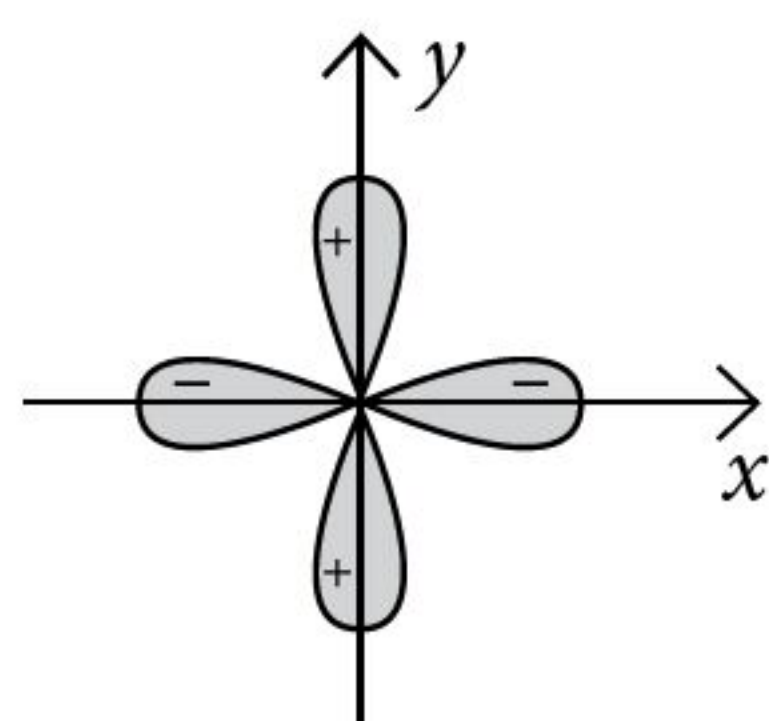
$$\Delta\nu = \frac{6.626 \times 10^{-34} \text{ J s}}{4 \times 3.14 \times 0.1 \times 10^{-10} \text{ m} \times 9.1 \times 10^{-31} \text{ kg}}$$

$$= 0.579 \times 10^7 \text{ m s}^{-1} = 5.79 \times 10^6 \text{ m s}^{-1}$$

28. (a) $2p$ has higher energy as $(n + l)$ value is higher for $2p$ than $2s$.

(b) Hund's rule of maximum multiplicity states that pairing of electrons in the orbitals of same subshell does not take place until each orbital of that subshell has one electron.

(c) Shape of $d_{x^2-y^2}$ orbital :



29. (a) (i) It failed to explain the stability of atoms. According to Rutherford's model, electrons are revolving around the nucleus thus, electrons would be in a state of acceleration all the time and should continuously emit radiations. They would get more closer to the nucleus and finally fall in the nucleus.

(ii) It failed to explain the distribution of electrons around the nucleus and did not tell anything about their energies.

(b) Since, most of the α -particles passed through the foil undeflected, this indicated that the most of the space in an atom is empty.

OR

(b) $\frac{\text{Diameter of atom}}{\text{Diameter of nucleus}} = \frac{2 \times 10^{-10}}{2 \times 10^{-15}} = 10^5$

(c) α -particles are He^{2+} ions.

30. (a) $\sqrt{S(S+1)} \frac{h}{2\pi} = \sqrt{\frac{1}{2} \left(\frac{1}{2} + 1 \right)} \frac{h}{2\pi}$

$$= \frac{\sqrt{3}}{2} \frac{h}{2\pi} = 0.866 \frac{h}{2\pi}$$

(b) 0

(c) Hund's rule

OR

(c) No two electrons in an atom can have same set of four quantum numbers.

31. (A) (a) Radius of n^{th} Bohr's orbit, $r_n = \frac{n^2 h^2}{4\pi^2 m Z e^2}$

For hydrogen atom $Z = 1$, first orbit $n = 1$

$$r_1 = \frac{h^2}{4\pi^2 m e^2} = 0.529 \text{ \AA}$$

(i) For He^+ ion, $Z = 2$, third orbit, $n = 3$

$$r_3(\text{He}^+) = \frac{3^2 h^2}{4\pi^2 m \times 2 \times e^2}$$

$$= \frac{9}{2} \left[\frac{h^2}{4\pi^2 m e^2} \right] = \frac{9}{2} \times 0.529 = 2.380 \text{ \AA}$$

(ii) For Li^{2+} ion, $Z = 3$, second orbit, $n = 2$

$$r_2(\text{Li}^{2+}) = \frac{2^2 h^2}{4\pi^2 m \times 3 \times e^2} = \frac{4}{3} \left[\frac{h^2}{4\pi^2 m e^2} \right]$$

$$= \frac{4}{3} \times 0.529 = 0.705 \text{ \AA}$$

(b) (i) $3p$

(ii) $1s$

OR

(B) (a) $\text{Cr}^+ : [\text{Ar}] 3d^5$

Number of unpaired electrons = 5

(b) For $2d$, $n = 2$, only two values are possible for $l = 0$ and 1 i.e., s and p , thus no d -orbital is possible for 2^{nd} shell.

For $3f$, $n = 3$, only three values are possible for $l = 0, 1$ and 2 i.e., s, p and d , thus no f -orbital possible is for 3^{rd} shell.



ANSWERS JUNE 2025

The 3 sets of trio are (TIO, TOI, OTI), (INE, ENI, EIN) and (VIN, NIV, NVI)

ENANTIOMER

DIPROTIC

PHOSPHINE

STOICHIOMETRY

ARSENIC

UNIVALENT

PHTHALEIN

VINYL

ENVIRONMENT

Winner: Soumili Mitra Roy

(c) No. of orbitals ($n = 5$) = n^2 or 5^2 or 25.

There will be total 50 electrons. 25 electrons will have

$$m_s = +\frac{1}{2} \text{ and 25 electrons will have } m_s = -\frac{1}{2}.$$

32. (A) (a) Wavelength of light (λ) = 616 nm
 $= 616 \times 10^{-9} \text{ m}$

(i) Frequency of emission (ν) = $\frac{c}{\lambda} = \frac{3 \times 10^8}{616 \times 10^{-9}}$
 $= 4.87 \times 10^{14} \text{ s}^{-1}$

(ii) Distance travelled in 30 sec
 $= 30 \times 616 \times 10^{-9} \times 4.87 \times 10^{14} \approx 9.0 \times 10^9 \text{ m}$

(iii) Energy of quanta (E) = $h\nu$
 $= 6.626 \times 10^{-34} \times 4.87 \times 10^{14}$
 $= 3.227 \times 10^{-19} \text{ J}$

(b) Energy of electron in the n^{th} orbit of H-atom is

$$E_n = \frac{-13.6}{n^2} \text{ eV} \therefore E_1 = -13.6 \text{ eV}$$

After absorbing 12.1 eV, the energy will be

$$= -13.6 + 12.1 \text{ eV} = -1.5 \text{ eV}$$

Thus, $\frac{-13.6}{n^2} = -1.5 \text{ eV}$ or $n^2 \approx 9$

or $n = 3$

Thus, electron will jump to 3rd orbit.

OR

(B) (a) Differences between orbit and orbitals :

	Orbit	Orbital
1.	Orbit is a well-defined 2D circular path around the nucleus in which the electrons revolve.	Orbital is a 3D motion of an electron around the nucleus within which the probability of finding the electrons is maximum.
2.	Concept of orbit is not in accordance with the wave nature of electrons.	It is in accordance with the wave nature of electrons.
3.	Orbits do not have directional characteristics.	All orbitals except s-orbital have directional characteristics.

(b) (i) The number of orbitals in a subshell is equal to $(2l + 1)$.

Since for a g-subshell, $l = 4$, the number of g-orbitals in a g-subshell is $(2 \times 4 + 1) = 9$.

(ii) Since, $l = 4$ for a g-subshell, therefore, the first principal electronic shell $n = l + 1 = 5$.

33. (A) (a) Light has a dual nature. Some times, it behaves like a particle (called a photon), which explains how light travels in straight line. The particle nature of light was explained by Einstein in the photoelectric effect. Some times, it behaves like a wave, which explains how light bends (or diffracts) around an object. The wave nature of light was first illustrated through experiments on diffraction and interference. Like all electromagnetic waves, light can travel through vacuum.

Scientists accept the evidence that supports this dual nature of light.

$$\lambda = \frac{h}{mv} = \frac{6.62 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}}{9.11 \times 10^{-31} \text{ kg} \times 2.19 \times 10^6 \text{ m s}^{-1}}$$

$$= 3.318 \times 10^{-10} \text{ m} = 3.32 \text{ \AA}$$

(b) Here, $\lambda = 242 \text{ nm} = 242 \times 10^{-9} \text{ m}$

$$I.E. = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{242 \times 10^{-9}}$$

$$= 8.21 \times 10^{-19} \text{ J/atom}$$

Ionisation energy of sodium in kJ mol^{-1}
 $= 8.214 \times 10^{-19} \times 10^{-3} \times 6.022 \times 10^{23}$
 $= 494.65 \text{ kJ mol}^{-1}$

OR

(B) (a) $\nu = \frac{E(\text{Photon})}{h} = \frac{3.5 \times 10^{-19}}{6.62 \times 10^{-34}}$
 $= 5.28 \times 10^{14} \text{ s}^{-1}$

Since the frequency of the radiation used $\nu < \nu_0$, i.e., threshold frequency or minimum frequency to show photoelectric effect, it will not show photoelectric effect.

(b) Angular momentum of the electron in an orbital
 $= \frac{h}{2\pi} \sqrt{l(l+1)}$

(i) $l = 0$ for 4s-orbital

$\therefore$ Angular momentum = 0

(ii) $l = 1$ for 3p-orbital

$$\therefore \text{Angular momentum} = \frac{h}{\sqrt{2}\pi}$$

(iii) Angular momentum in an orbit = $\frac{nh}{2\pi}$
 $n = 4$ for 4th orbit

$$\therefore \text{Angular momentum} = \frac{2h}{\pi}$$



NEET / JEE

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Unit 1 The *p*-Block Elements (Group 15 to 18) | Polymers

The *p*-BLOCK ELEMENTS (GROUP 15 TO 18)

The *p*-block elements are placed in groups 13 to 18 of the periodic table. These elements have 3, 4, 5, 6, 7 and 8 electron in their outermost shell. Their valence shell electronic configuration is $ns^2 np^{1-6}$ (except He).

GROUP 15 ELEMENTS (NITROGEN FAMILY)

Group 15 of the periodic table consists of six elements viz, nitrogen (N), phosphorus (P), arsenic (As), antimony (Sb), bismuth (Bi) and moscovium (Mc). The first two elements of this groups *i.e.*, nitrogen and phosphorus are non-metals, the next two, arsenic and antimony are metalloids whereas the element, bismuth is a metal. They are collectively called as pnictogens.

Element	At. No.	Electronic Configuration	Oxidation State
Nitrogen (N)	7	[He] $2s^2 2p^3$	-3, -2, -1, 0, +1, +2, +3, +4, +5
Phosphorus (P)	15	[Ne] $3s^2 3p^3$	-3, +3, +5
Arsenic (As)	33	[Ar] $3d^{10} 4s^2 4p^3$	-3, +3, +5
Antimony (Sb)	51	[Kr] $4d^{10} 5s^2 5p^3$	-3, +3, +5
Bismuth (Bi)	83	[Xe] $4f^{14} 5d^{10} 6s^2 6p^3$	+3, +5
Moscovium (Mc)	115	[Rn] $5f^{14} 6d^{10} 7s^2 7p^3$	-

General Characteristics

- **Physical state:** Nitrogen is a gas, phosphorus is a soft waxy solid, arsenic is hard but lustreless while antimony and bismuth are hard solids with metallic lustre.
- **Atomic radii:** The atomic radii increase with the increase in atomic number. There is considerable increase in covalent radius from N to P, this is due to effective shielding of *s*- and *p*-electrons of the penultimate shell in phosphorus. Small increase in covalent radii from As to Bi is, however due to poor shielding effect of *d*- and/or *f*-electrons present in the inner shells on valence electrons.
- **Ionisation enthalpy :** The ionisation enthalpy decreases regularly on descending the group as atomic radii increases. The difference between N and P is comparatively high due to small size of N but the difference afterwards between two consecutive members is small. This is due to less shielding effect of *d*-electrons in As and Sb, and similarly of *d*- and *f*-electrons in Bi.
- **Electronegativity :** The electronegativity of group 15 elements decreases due to gradual increase in the atomic radii of the elements as we move from N to Bi.

Important physical properties of Group 15 elements

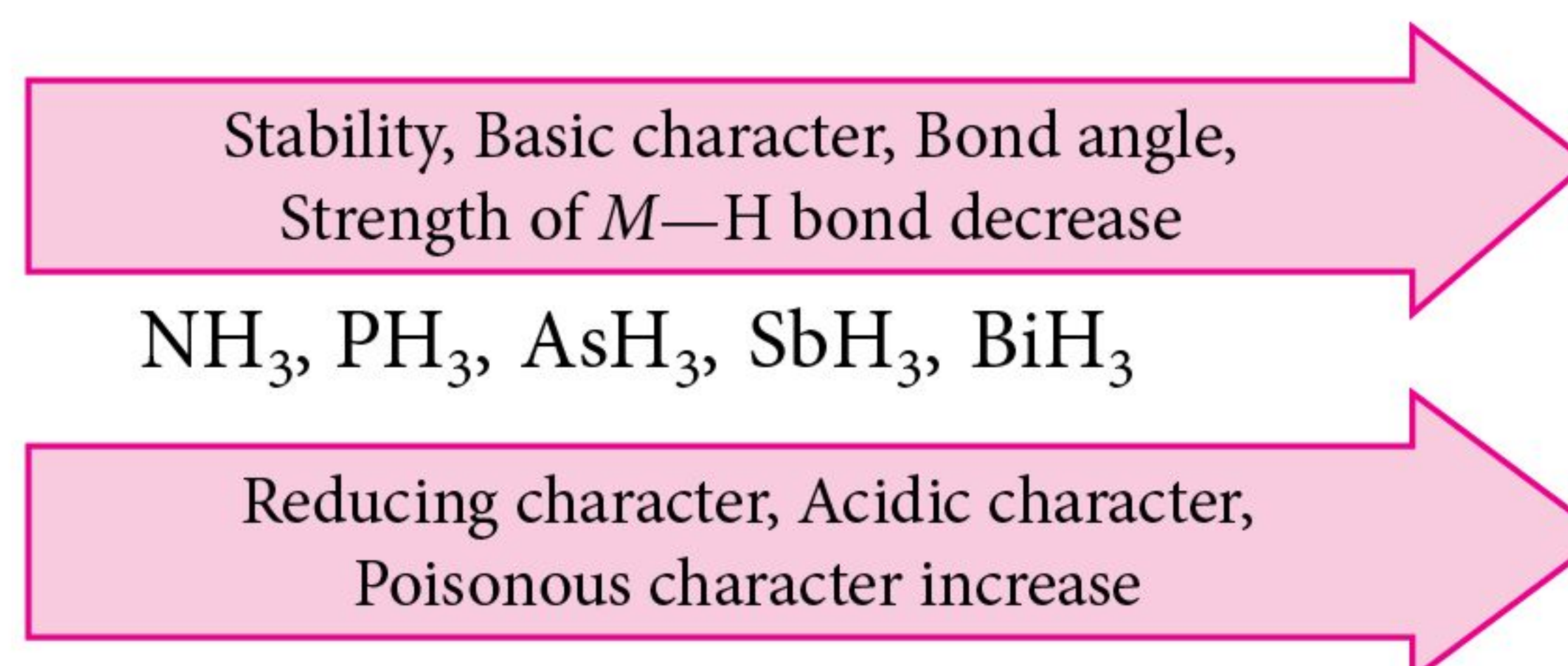
Property	N	P	As	Sb	Bi
Atomic number	7	15	33	51	83
Atomic mass (g mol ⁻¹)	14.01	30.97	74.92	121.75	208.98
Ionisation enthalpy I ($\Delta H/\text{kJ mol}^{-1}$)	1402	1012	947	834	703
Ionisation enthalpy II	2856	1903	1798	1595	1610
Ionisation enthalpy III	4577	2910	2736	2443	2466
Electronegativity	3.0	2.1	2.0	1.9	1.9
Covalent radius/pm ^a	70	110	121	141	148
Ionic radius/pm	171 ^b	212 ^b	222 ^b	76 ^c	103 ^c
Melting point/K	63 [*]	317 ^d	1089 ^e	904	544
Boiling point/K	77.2 [*]	554 ^d	888 ^f	1860	1837
Density/[g cm ⁻³](298 K)	0.879 ^g	1.823	5.778 ^h	6.697	9.808

^a E^{III} single bond (E = element); ^b E^{3-} ; ^c E^{3+} ; ^dWhite phosphorus; ^eGrey α -form at 38.6 atm; ^fSublimation temperature; ^gAt 63K; ^hGrey α -form; ^{*}Molecular N₂.

- Melting and boiling points** : M.pt of group 15 elements first increase from N to As due to increase in their atomic size and then decrease to Sb and Bi because of their tendency to form three covalent bonds instead of five due to inert pair effect.
- Non-metallic and metallic character** : Down the group, metallic character increases.
- Allotropy** : All the elements, except bismuth, show allotropy. Phosphorus exists in three allotropic forms such as white or yellow, red or violet and black phosphorus.

Chemical Properties

- Hydrides** : Form MH_3 type hydrides.
 - Melting point** : $PH_3 < AsH_3 < SbH_3 < NH_3$
 - Boiling point** : $BiH_3 > SbH_3 > NH_3 > AsH_3 > PH_3$
 - Bond angle** : $NH_3 > PH_3 > AsH_3 > SbH_3 > BiH_3$
(107.8°) (93.6°) (91.8°) (91.3°) (90°)



- Halides** : Nitrogen forms MX_3 type of halides while rest other form both MX_3 and MX_5 types of halides.
 - Stability** : $NF_3 > NCl_3 > NBr_3$
 - Bond angle** : $PF_3 < PCl_3 < PBr_3 < PI_3$
 - Lewis acid strength** : $PCl_3 > AsCl_3 > SbCl_3$
 $PF_3 > PCl_3 > PBr_3 > PI_3$
 - Lewis base strength** : $NI_3 > NBr_3 > NCl_3 > NF_3$
- Oxides** : All these elements form oxides of the types M_2O_3 , M_2O_4 and M_2O_5 .

N ₂ O ₃	P ₄ O ₆	As ₄ O ₆	Sb ₄ O ₆	Bi ₂ O ₃	Acidic nature increases ↓
N ₂ O ₄	P ₄ O ₈	—	—	—	
N ₂ O ₅	P ₄ O ₁₀	As ₄ O ₁₀	Sb ₄ O ₁₀	—	

Structures of the oxides of nitrogen

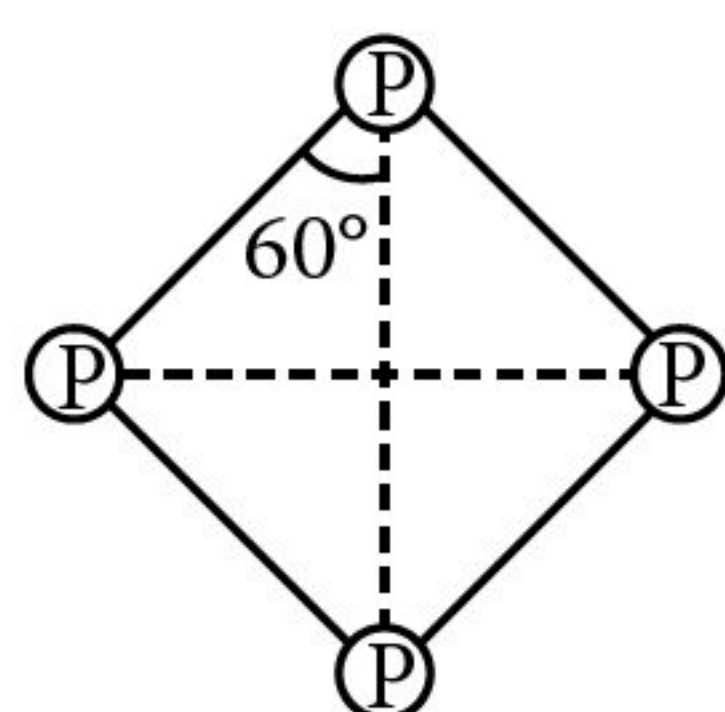
Oxide	Oxidation state	Physical appearance	Structure
N ₂ O (Nitrous oxide)	+1	Colourless gas	$N \equiv N \rightarrow O$
NO (Nitric oxide)	+2	Colourless gas	$N = O$
N ₂ O ₃ (Dinitrogen trioxide)	+3	Blue coloured solid	$O=N-N \begin{matrix} \nearrow O \\ \searrow O \end{matrix}$

N_2O_4 (Dinitrogen tetroxide)	+4	Colourless solid	
NO_2 (Nitrogen dioxide)	+4	Brown gas	
N_2O_5 (Dinitrogen pentoxide)	+5	Colourless solid	

Allotropes of Phosphorus

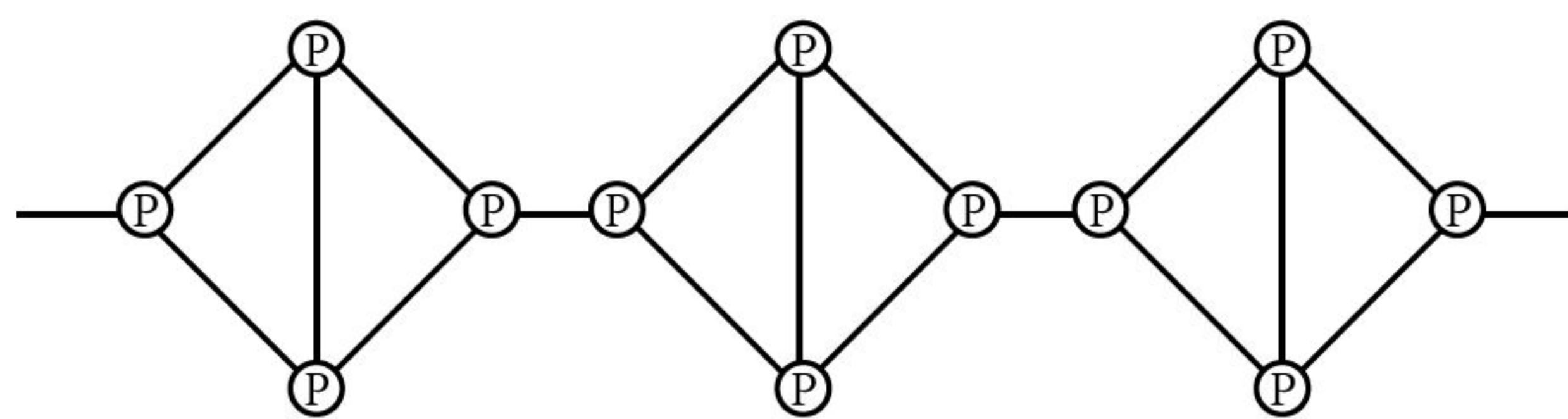
Property	White phosphorus	Red phosphorus	Black phosphorus
Colour	White, but turns yellow on exposure	Dark red	Black
State	Waxy solid, can be cut with knife	Brittle powder	Crystalline with greasy touch
Smell	Garlic smell	Odourless	—
Density	1.84	2.1	2.69
Ignition temperature	307 K	543 K	does not burn in air even upto 673 K
Melting point	317 K	Sublimes in absence of air at 560 K	860 K

- White phosphorus consists of discrete tetrahedral P_4 molecule.



Structure of white phosphorus

- Red phosphorus is polymeric and consists of interlinked P_4 tetrahedral.



Structure of red phosphorus

- Black phosphorus is thermodynamically most stable at room temperature and has two forms :

- α -Black phosphorus
- β -Black phosphorus

Oxoacids of Phosphorus

Oxoacid	Structure
Phosphinic acid (Hypophosphorous acid), H_3PO_2	Basicity = 1 O.S. of P = +1
Phosphonic acid (Orthophosphorous acid or phosphorous acid), H_3PO_3	Basicity = 2 O.S. of P = +3
Phosphoric acid (Orthophosphoric acid), H_3PO_4	Basicity = 3 O.S. of P = +5
Metaphosphoric acid (Glacial phosphoric acid), $(\text{HPO}_3)_n$	Basicity = 1 O.S. of P = +5
Pyrophosphorous acid (diphosphorous acid), $\text{H}_4\text{P}_2\text{O}_5$	Basicity = 2 O.S. of P = +3
Pyrophosphoric acid (diphosphoric acid), $\text{H}_4\text{P}_2\text{O}_7$	Basicity = 4 O.S. of P = +5
Hypophosphoric acid, $\text{H}_4\text{P}_2\text{O}_6$	Basicity = 4 O.S. of P = +4

GROUP 16 ELEMENTS (OXYGEN FAMILY)

Group 16 of the long form of the periodic table contains six elements namely oxygen (O), sulphur (S), selenium (Se), tellurium (Te), polonium (Po) and livermorium (Lv).

Physical Properties

Property	Oxygen	Sulphur	Selenium	Tellurium	Polonium
Atomic number	8	16	34	52	84
Atomic mass/g mol ⁻¹	15.999	32.064	78.96	127.60	210
Density/g cm ⁻³ (298 K)	1.32	2.07	4.19	6.23	–
Atomic radius (pm)	66	104	117	137	146
Ionic radius of divalent ion (pm)	140	184	198	221	–
Ionisation energy/kJ mol ⁻¹	1313.7	999.4	940.9	869.5	813.5
Oxidation states	-2, -1, (+1, +2)	-2, +2, +4, +6	-2, +2, +4, +6	-2, +2, +4, +6	+2, +4
Electronegativity	3.50	2.58	2.55	2.01	1.76
Melting point (K)	55	393	490	725	520
Boiling point (K)	90	718	958	1260	1235
Electron gain enthalpy (kJ mol ⁻¹)	-141	-200	-195	-190	-174

Chemical Properties

Stability of -2 oxidation state decreases down the group, stability of +4 oxidation state increases and that of +6 oxidation state decreases down the group due to inert pair effect.

Hydrides :

- All the elements of this group form the hydrides of H₂M type, where M = O, S, Se, Te and Po.
- The volatility of these hydrides increases markedly from H₂O to H₂S and then decreases. Abnormal low volatility of H₂O (i.e., high boiling point) is due to its association as a result of hydrogen bonding both in solid and liquid states.
- The thermal stability of the hydrides decreases from H₂O to H₂Te due to increased M—H bond length.
- Aqueous solutions of the hydrides of these elements behave as weak, diprotic acids and hence ionise as
$$\text{H}_2\text{M} \longrightarrow \text{H}^+ + \text{HM}^-$$
$$\text{HM}^- \longrightarrow \text{H}^+ + \text{M}^{2-}$$
- The acidic character of these acids increases in the sequence from H₂S to H₂Te due to decrease in bond (H—M) dissociation energy down the group.
- All these hydrides are V-shaped. In these hydrides, the central atom is sp³ hybridized. The bond angles are 104.5°, 92.5°, 91° and 90° in H₂O, H₂S, H₂Se and H₂Te, respectively. This can be explained on

the basis of decreasing electronegativity of central atom and decreasing tendency of sp³ hybridization.

the basis of decreasing electronegativity of central atom and decreasing tendency of sp³ hybridization.

- **Boiling point** : H₂O > H₂Te > H₂Se > H₂S
- **Volatility** : H₂S > H₂Se > H₂Te > H₂O
- **Bond angle** : H₂O > H₂S > H₂Se > H₂Te
- **Acidic character** : H₂O < H₂S < H₂Se < H₂Te
- **Reducing power** : H₂Te > H₂Se > H₂S > H₂O

Halides :

- SF₄ is gaseous, SeF₄ is liquid and TeF₄ is solid.
- SF₆ is extremely stable and chemically inert.
- Chemical reactivity of hexafluorides follows the order : SF₆ < SeF₆ < TeF₆
- Stability of hexafluorides decreases from SF₆ to TeF₆.
$$\text{SF}_6 > \text{SeF}_6 > \text{TeF}_6$$

Oxides :

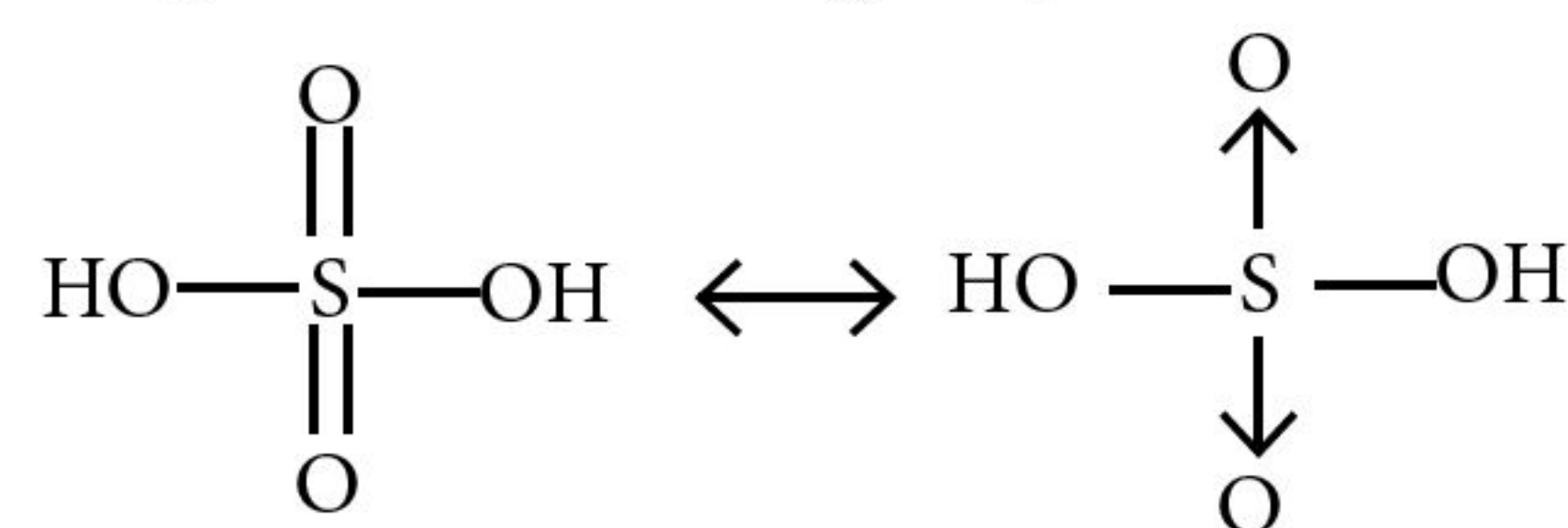
- All the elements of group-16 form two types of oxides EO₂ and EO₃. (where, E = S, Se, Te, or Po) e.g., O₃, SO₂, SeO₂, TeO₂, PoO₂, SO₃, SeO₃, TeO₃.
- O₃ (Ozone) and SO₂ (Sulphur dioxide) are gases while all other oxides are solids.
- Oxides of group-16 are acidic in nature. Acidic character decreases from S to Te.
- Trioxides are more acidic than dioxides.

- Reducing property of dioxides decreases from SO_2 to TeO_2 . SO_2 is a reducing agent while TeO_2 is an oxidising agent.

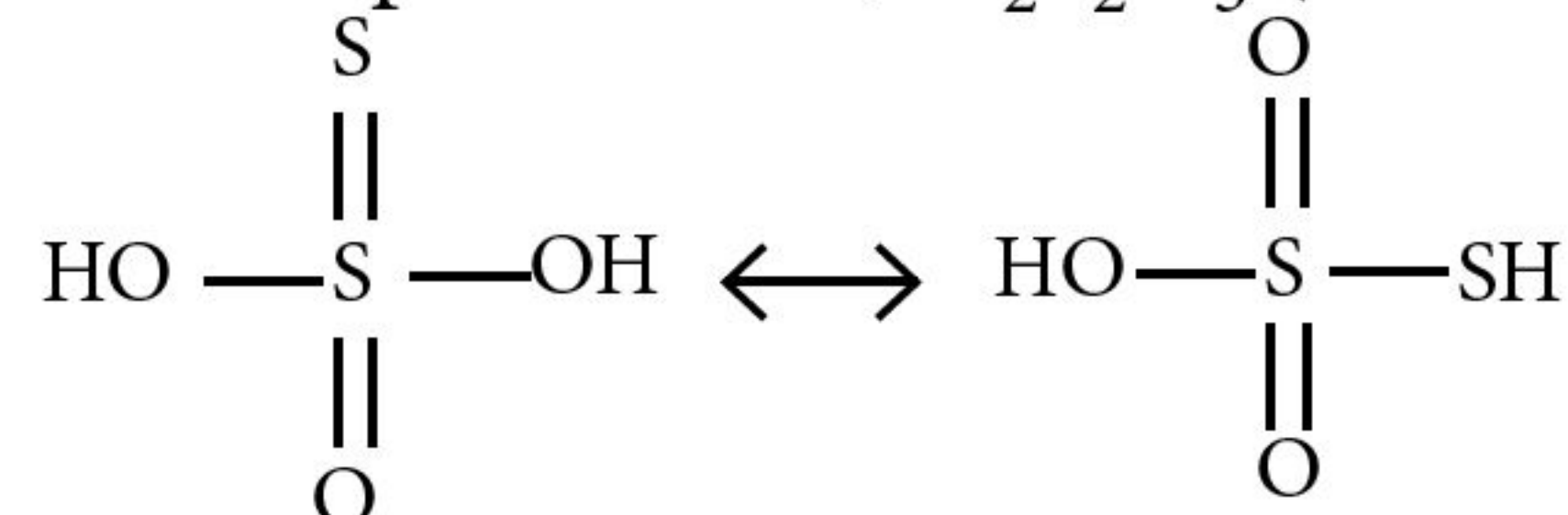
Allotropic Forms of Sulphur

Property	Rhombic or α -sulphur	Monoclinic or β -sulphur	Plastic sulphur
Colour	Pale yellow	Amber yellow	Amber brown
Specific gravity	2.06	1.96	1.95
Solubility in CS_2	Soluble	Soluble	Insoluble
Structure	S_8 puckered ring in crown shape	S_8 puckered ring in crown shape	Random arrangement of chains of S-atoms
Stability	Below 96°C	Above 95.6°C	Gradually changes in rhombic sulphur

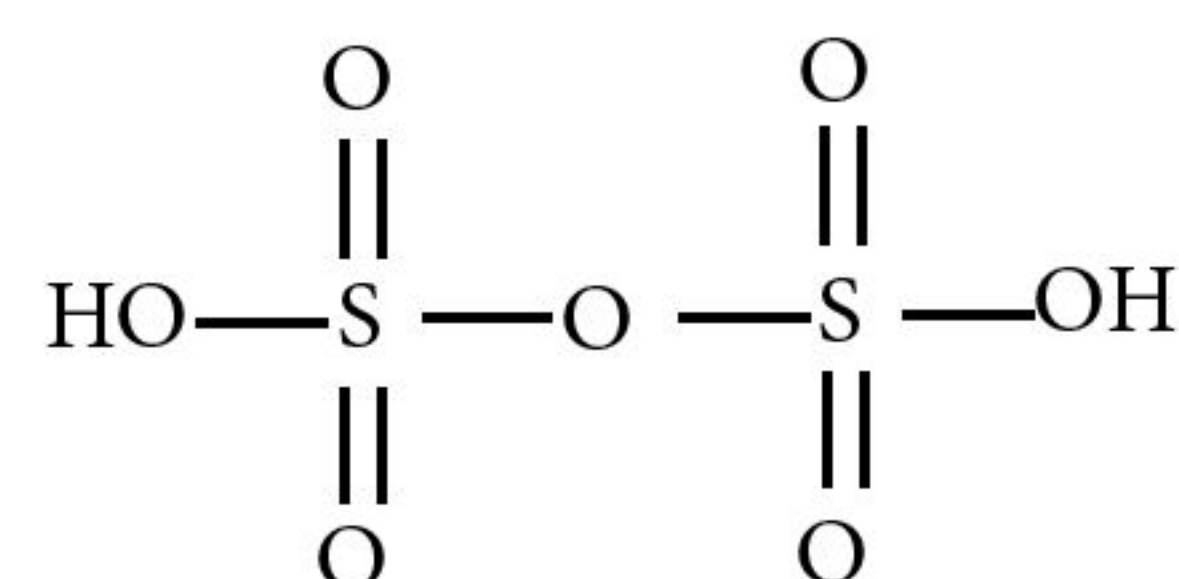
- Sulphuric Acid, H_2SO_4 ,



- Thiosulphuric acid, $\text{H}_2\text{S}_2\text{O}_3$ (unstable),

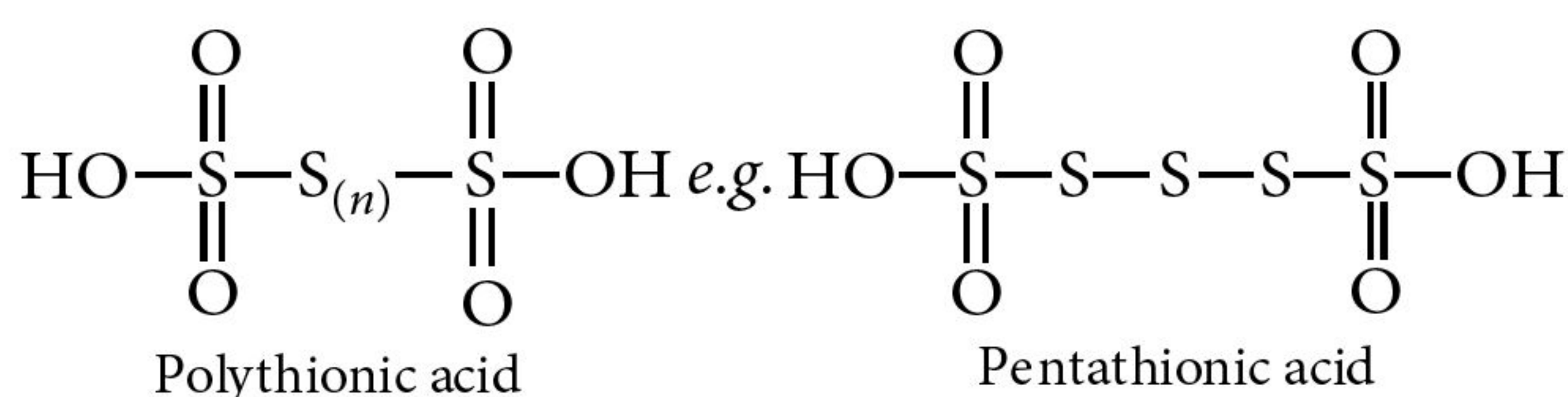


- Pyrosulphuric acid, $\text{H}_2\text{S}_2\text{O}_7$ (oleum),



- Dithionic acid, $\text{H}_2\text{S}_2\text{O}_6$, $\text{HO}-\overset{\text{O}}{\parallel}{\text{S}}-\overset{\text{O}}{\parallel}{\text{S}}-\text{OH}$

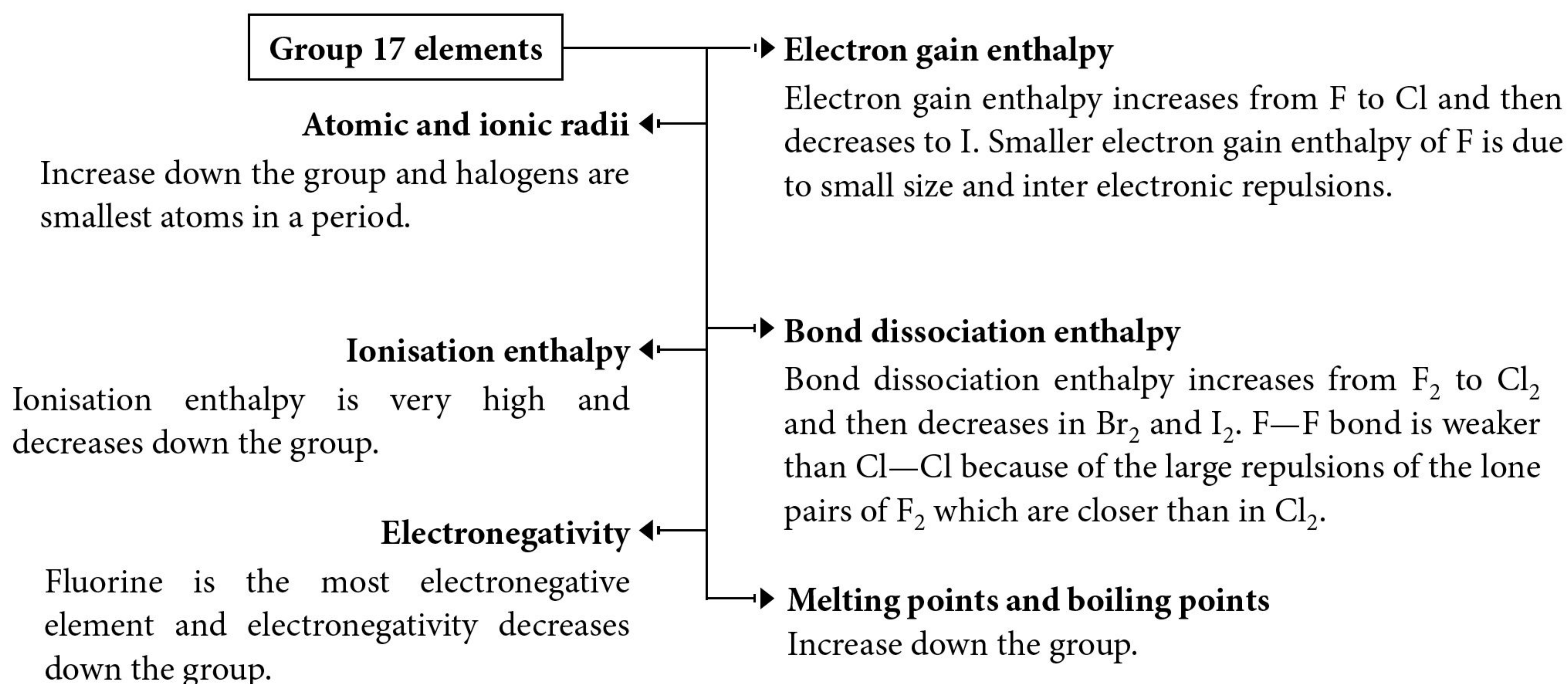
- Polythionic acid, $\text{H}_2\text{S}_n\text{O}_6$, ($n = 3, 4, 5, 6, \dots$)



GROUP 17 ELEMENTS (HALOGEN FAMILY)

Halogen Family The elements fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), Astatine (At) and Tennessine (Ts) constitute group 17 of the periodic table. These elements are collectively known as the halogens means salt producing.

Physical Properties



Chemical Properties

- F shows only -1 oxidation state while other elements show -1 , $+1$, $+3$, $+5$ and $+7$ oxidation states also.
- Reactivity** : $F_2 > Cl_2 > Br_2 > I_2$
- All halogens form covalent hydrides.
 $H_2 + X_2 \rightarrow 2HX$
- Hydrogen fluoride is a low boiling liquid (b.p. 292 K) while HCl, HBr and HI are gases. The anomalous property of HF is due to presence of hydrogen bonding in the molecules. Due to hydrogen bonding in HF molecules it exists as associated molecule $(HF)_n$.
- The thermal stability of the hydrides decreases from HF to HI. HF is most stable whereas HI is least stable. Decrease in stability of the hydrides is due to decrease in bond strength which decreases as we go down the group.

- HF is the weakest acid and HI is the strongest acid among these halogen hydrides.
- Fluorine is the most electronegative halogen. Thus HF, should be more ionic in nature and consequently it should be strongest acid. The major factor is the bond dissociation energy. The bond dissociation energy decreases from HF to HI so that HF has highest bond dissociation energy and HI has the lowest value.
 - Boiling points** : $HF > HI > HBr > HCl$
 - Melting points** : $HI > HF > HBr > HCl$
 - Bond length** : $HI > HBr > HCl > HF$
 - Bond dissociation enthalpy** : $HF > HCl > HBr > HI$
 - Acidic strength** : $HI > HBr > HCl > HF$
 - Thermal stability** : $HF > HCl > HBr > HI$
 - Reducing power** : $HI > HBr > HCl > HF$

Variation of the general properties of oxoacids of halogens					
Halogen	Hypohalous acids (X = +1)	Halous acids (X = +3)	Halic acids (X = +5)	Perhalic acid (X = +7)	
F	HOF	—	—	—	Electronegativity decreases Thermal stability decreases Oxidising power decreases Acidic strength decreases
Cl	HClO	HClO ₂	HClO ₃	HClO ₄	
Br	HBrO	—	HBrO ₃	—	
I	HIO	—	HIO ₃	HIO ₄	
Oxidation number of the central atom increases (+1, +3, +5, +7) $\longrightarrow$ Thermal stability increases $\longrightarrow$ Covalent character of X—O bond increases $\longrightarrow$ Oxidising power decreases $\longrightarrow$ Basicity decreases $\longrightarrow$ Electronegativity of the central atoms remains the same $\longrightarrow$					

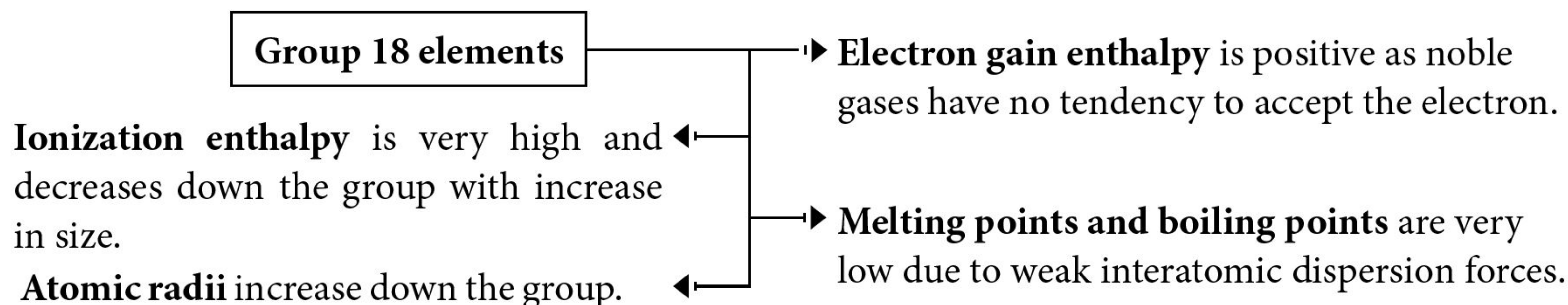
Interhalogen Compounds

Type	Hybridisation	Shape	Structure
AX	sp^3	Linear	
AX ₃	sp^3d	T-shaped	

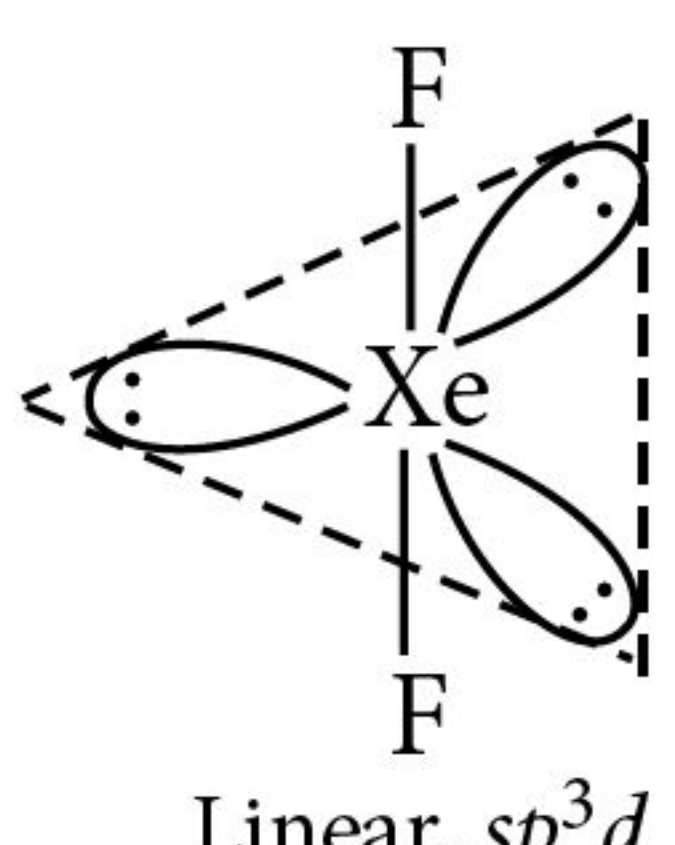
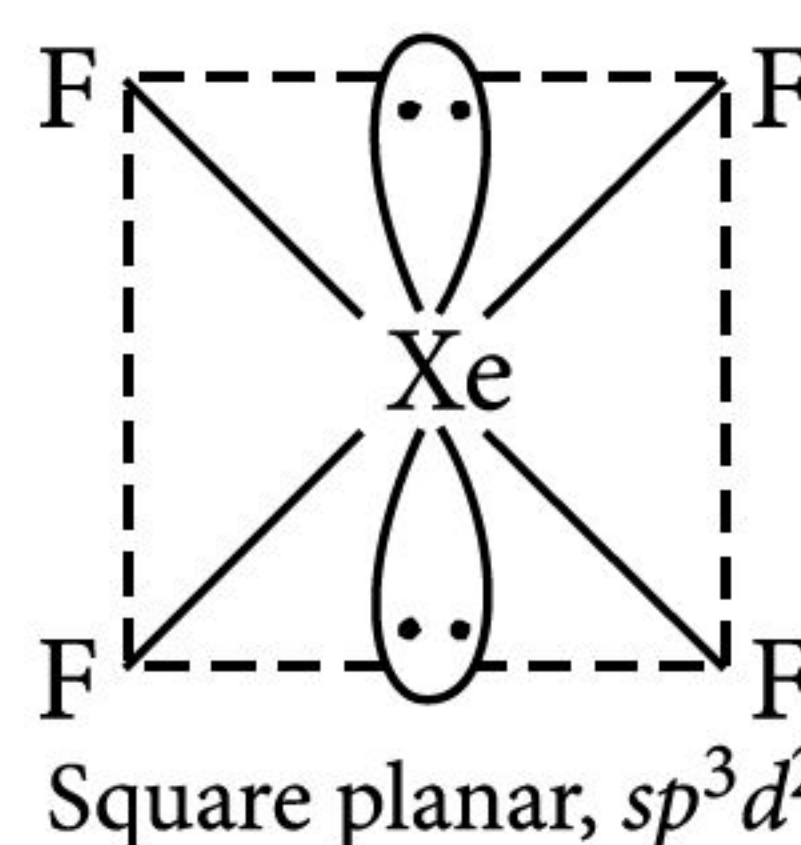
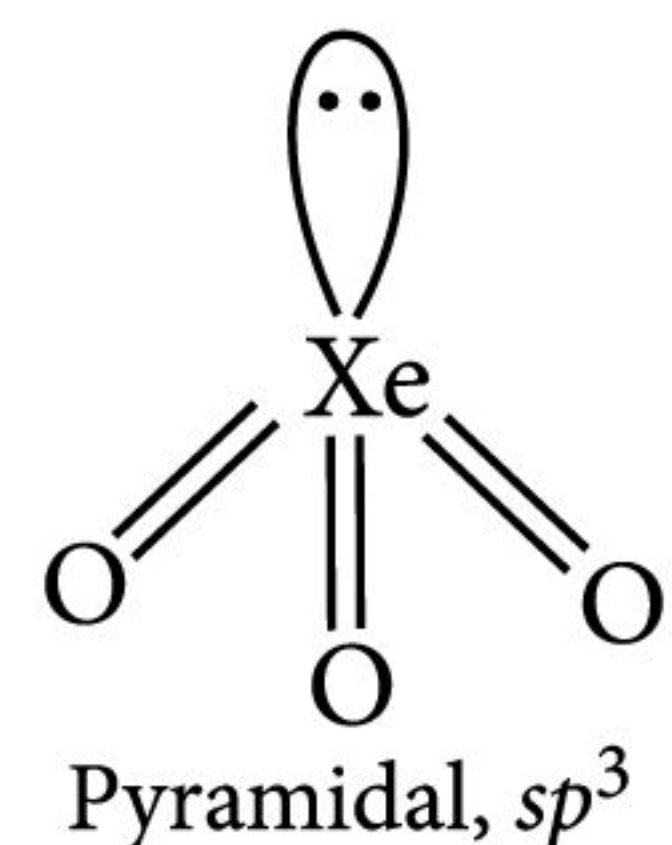
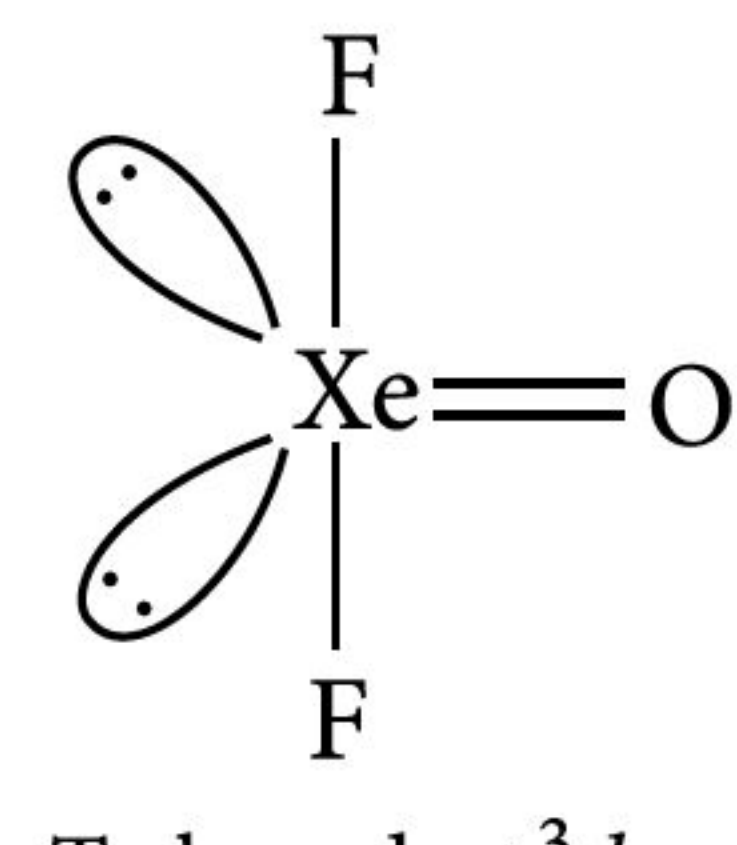
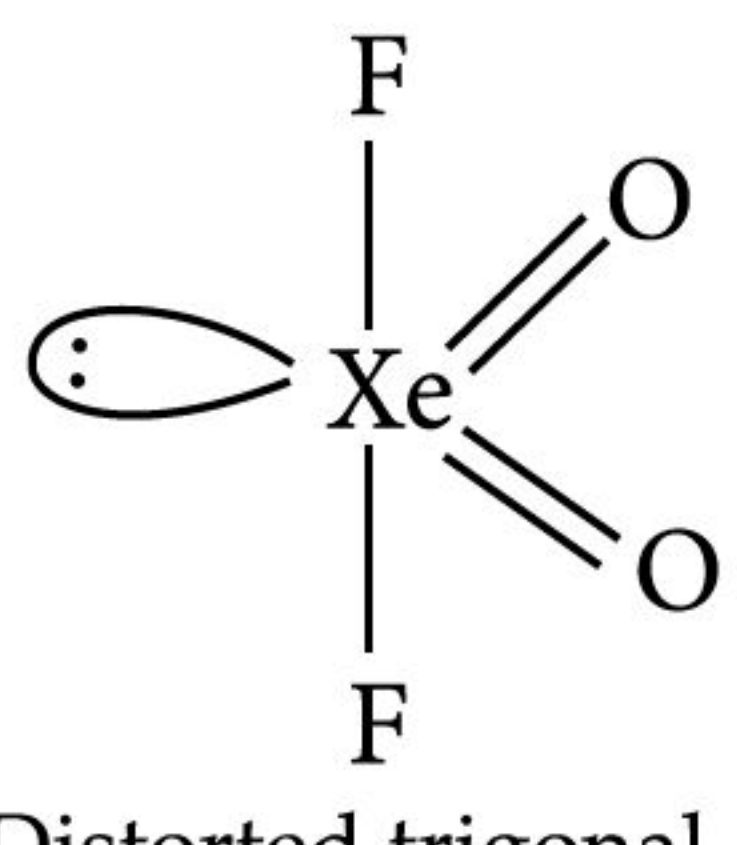
AX ₅	sp^3d^2	Square pyramidal	
AX ₇	sp^3d^3	Pentagonal bipyramidal	

GROUP 18 ELEMENTS (NOBLE GASES)

Group 18 of the long form of the periodic table contains elements namely Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Redon (Rn) and Oganesson (Og). These are also called noble gases.



Compounds of Xenon

Compound	XeF ₂ (Xenon difluoride)	XeF ₄ (Xenon tetrafluoride)	XeO ₃ (Xenon trioxide)	XeOF ₂ (Xenon oxydifluoride)	XeO ₂ F ₂ (Xenon dioxy- difluoride)
Structure	 Linear, sp^3d	 Square planar, sp^3d^2	 Pyramidal, sp^3	 T-shaped, sp^3d	 Distorted trigonal bipyramidal or see-saw shape, sp^3d

POLYMERS

Polymers are very large molecules having molecular mass ($10^3 - 10^7$ u), and hence are also called macromolecules. They are the backbone of few major chemical industries, viz, plastics, elastomers, fibres, paints and varnishes.

Polymers or macromolecules have very high molecular mass, which are formed by joining of repeating structural units through covalent bonds.

SOME IMPORTANT TERMS

RELATED TO POLYMERS

- **Monomers** : The simple molecules that combine together to give polymer are called monomers *e.g.*, ethene molecules are monomers of polyethene polymer.
- **Repeating units** : The part of a polymer, which is repeated at a regular interval is called repeating unit. It may or may not be same as monomer.
- **Macromolecules** : The polymers are also called as macromolecules because of the large size of their molecules. They are used frequently without any distinction. But a polymer will always consist of thousands of repeating monomers unit *e.g.*, chlorophyll is macromolecule but not a polymer

because it does not contain monomer units. Polythene can be called as polymers as well as macromolecule. Hence, it can be said that all the polymers are macro molecules but all macromolecules are not polymers.

CLASSIFICATION OF POLYMERS

Classification on the Basis of Origin

- **Natural polymers** : These are available in nature (animals or plants), examples of such polymers are: natural rubber (1,4-*cis*-polyisoprene), natural silk, cellulose, starch, etc. Proteins which make much of our body, nucleic acids which control heredity at molecular level and rubber which is used for making various articles of daily use are all natural polymers.
- **Semi-synthetic polymers** : These are the substances which are obtained by using natural polymers, *i.e.*, some modification are made in natural polymers by artificial means. Nitrocellulose, cellulose acetate, vulcanized rubber, gun cotton (cellulose trinitrate) and cellulose xanthate, etc., belong to this class of polymers.

- **Synthetic polymers :** These are man made polymers prepared synthetically such as polyethylene, polystyrene, polyvinyl chloride, polyesters, Bakelite, Buna-S, Nylon, Dacron, etc.

Classification on the Basis of Molecular Forces

- **Thermoplastic polymers :** These are the polymers which can be easily softened on heating and hardened on cooling. These are the polymers in which intermolecular forces of attraction are neither very strong nor very weak and there are no cross-links between the chains. These can be easily moulded by heating. *e.g.*, Polyethylene, polypropylene, polystyrene, polyvinyls etc. There are certain plastics which do not soften very much on heating. These can be easily softened by the addition of some organic compounds which are called plasticizers. For example, polyvinyl chloride (PVC) is very stiff and hard but it is made soft by adding di-*n*-butylphthalate (a plasticizer).
- **Thermosetting polymers :** These are semi-fluid substances with low molecular masses which when heated in a mould, undergo a permanent change in chemical composition to give a hard, infusible and insoluble mass. This hardening on heating is due to extensive cross-linking between different polymer chains to give a three-dimensional network solid. Thermosetting polymer can be heated only once when it undergoes a permanent change and sets into a solid which cannot be remelted and reworked. Some examples of thermosetting polymers are : phenol-formaldehyde (bakelite), urea-formaldehyde, melamine-formaldehyde, etc.
- **Fibres :** These are the polymers which have strong intermolecular forces between chains. These forces are either H-bonds or dipole-dipole interaction. These strong forces also lead to close packing of chains and thus impart crystalline nature. These have high tensile strength and least elasticity. Therefore, they have sharp melting points and low solubility. These polymers are long, thin and thread like and can be woven in fabrics. Some of the example of these polymers are nylon-6,6, silk, dacron etc.
- **Elastomers :** Polymers with elastic character like rubber are called elastomers. In elastomers the polymer chains are bound together by weakest intermolecular forces, like van der Waal's force of attraction. These are easily stretched by applying

small stress and regains its original shape when stress is removed. For example, natural rubber.

Differences between thermoplastic and thermosetting polymers

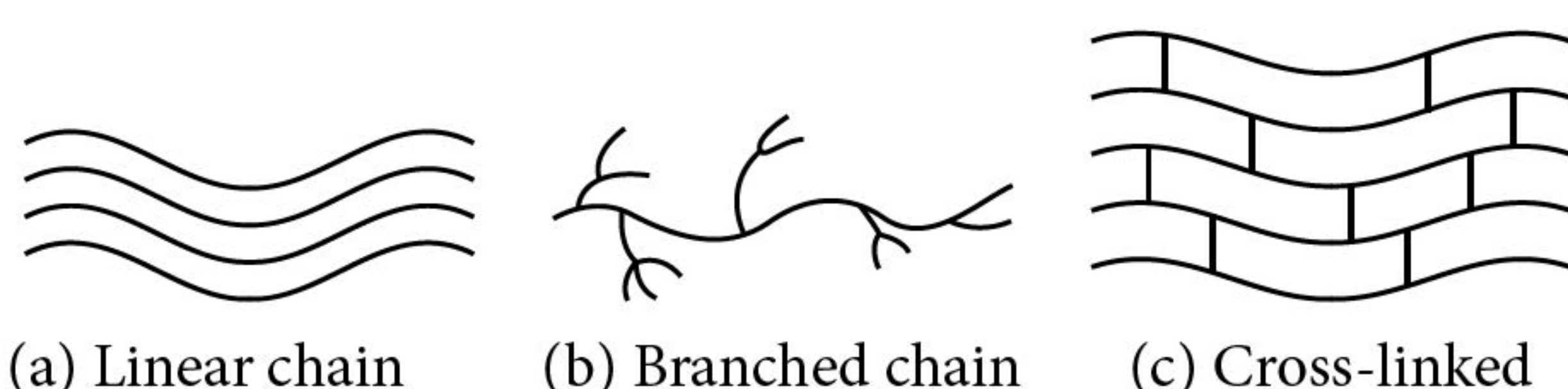
	Thermoplastic polymers	Thermosetting polymers
1.	These soften and melt on heating.	These do not soften on heating but rather become hard. In case prolonged heating is done, these start burning.
2.	These can be remoulded, recast and reshaped.	These cannot be remoulded or reshaped.
3.	These are less brittle and soluble in some organic solvents.	These are more brittle and insoluble in organic solvents.
4.	These are formed by addition polymerisation.	These are formed by condensation polymerisation.
5.	These have usually linear structures.	These have three dimensional cross-linked structures.
6.	Examples : Polyethylene, PVC, Teflon, Nylon, etc.	Examples : Bakelite, Urea - Formaldehyde, Resin, Terylene, etc.

Classification on the Basis of Structure

- **Linear polymers :** These are the polymers in which the monomers are joined together to form long straight chains. The various polymeric chain are then stacked over on another to give a well packed structure as given in figure (a). As a result of close packing, such polymers have high melting points, high densities (HDP) and high tensile strength. The examples of such type of polymers are polythene, PVC, polyesters and nylons, etc. These may be termed as one dimensional polymers.
- **Branched chain polymers :** In these polymers, the monomeric units are joined to produce long chains (called the main chain) along with side-chain of different length which produce branches as given in figure (b). Branched chain polymers are irregularly packed and as a result they have lower melting points, low density (LDP) and lower

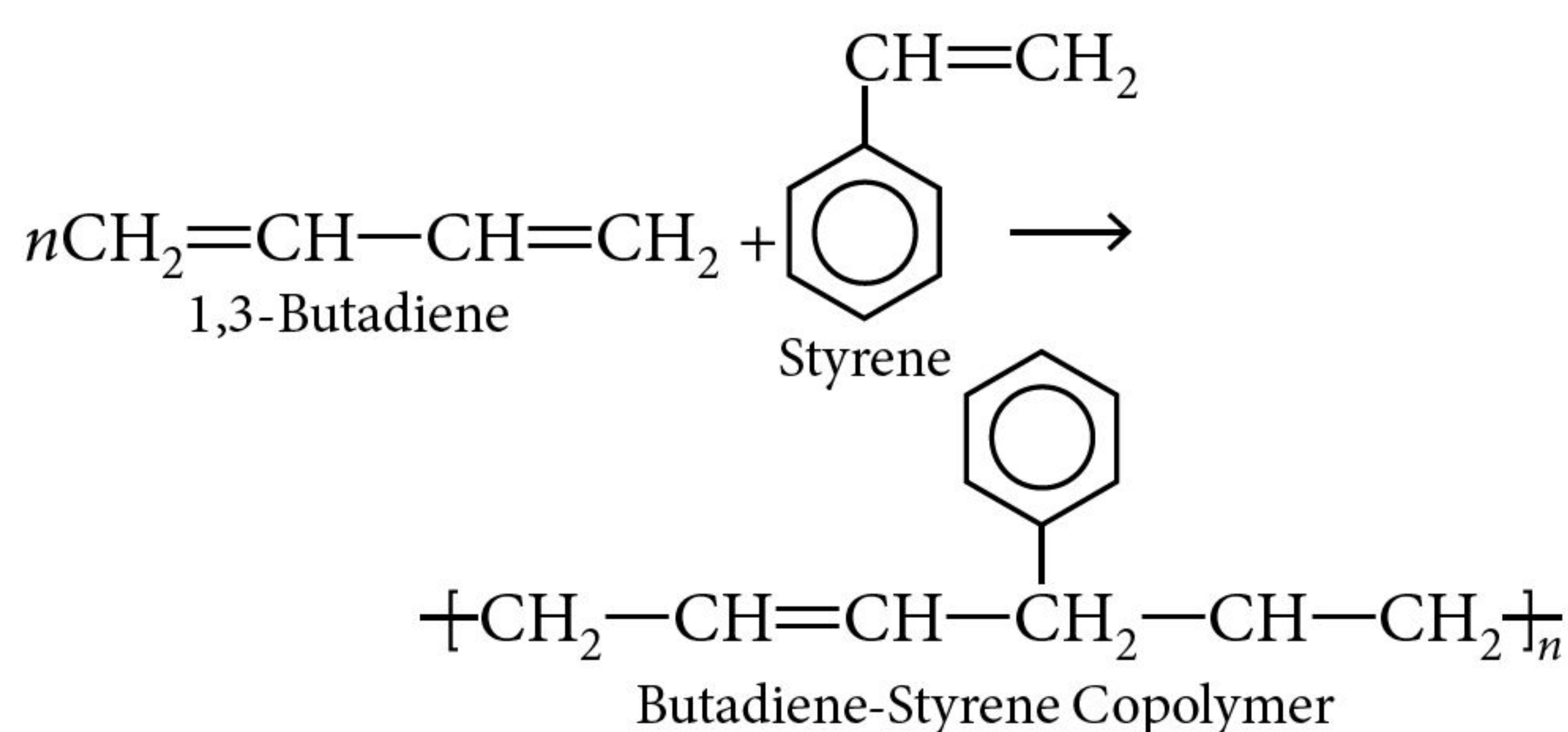
tensile strength as compared to linear polymers. An important example of a branched chain polymer is low density polythene. Others are amylopectin and glycogen, etc. Their molecules are two dimensional.

- **Cross-linked polymers** : In these polymers, the initially formed linear polymer chains are joined together to form a three dimensional network structure as given in figure (c). The links involved are called cross-links and these polymers are called cross-linked polymers. These polymers are hard, rigid and brittle because of their network structure. Solids are termed as three dimensional polymers. Examples are : Bakelite, urea-formaldehyde polymer, melamine formaldehyde (melmac) resins, etc.



Copolymerisation

- Copolymerisation is a polymerisation reaction in which a mixture of more than one monomeric species is allowed to polymerise to form a copolymers. Copolymers can be prepared by both chain growth and step growth polymerisation. For example a mixture of 1, 3-butadiene and styrene can form a copolymer; Butadiene-Styrene copolymer.

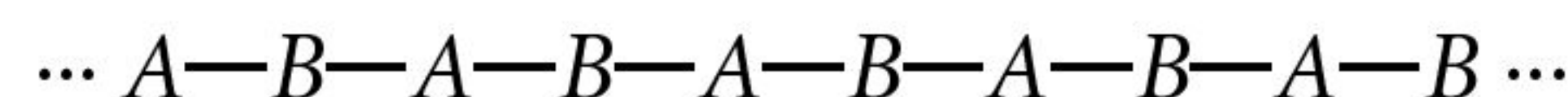


- The properties of a copolymer are entirely different from a physical mixture of the two individual polymers. Copolymers have better physical and mechanical properties. For example, Buna-S or SBR (Styrene butadiene rubber) is a copolymer of styrene and buta-1,3-diene. Polystyrene is easily breakable but polybutadiene is flexible. The copolymer, SBR is more flexible than polybutadiene and tougher than polystyrene. The properties could be changed by varying the amounts of each monomer.

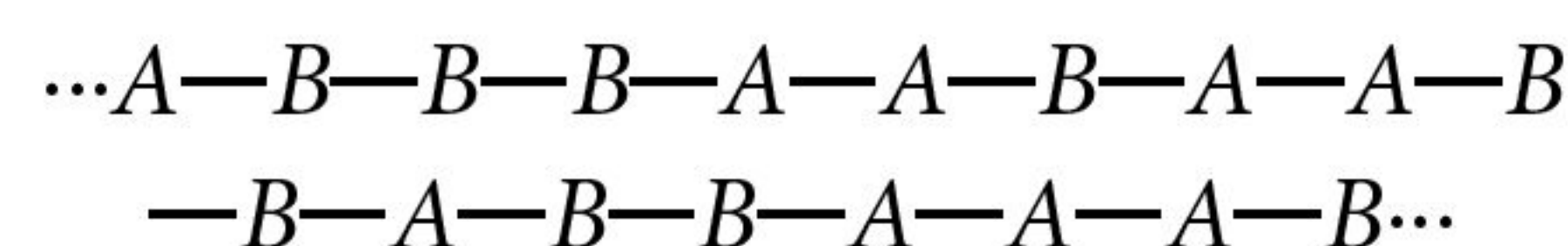
Types of Copolymer

Depending upon the distribution of monomer units, the following four types of copolymers are possible :

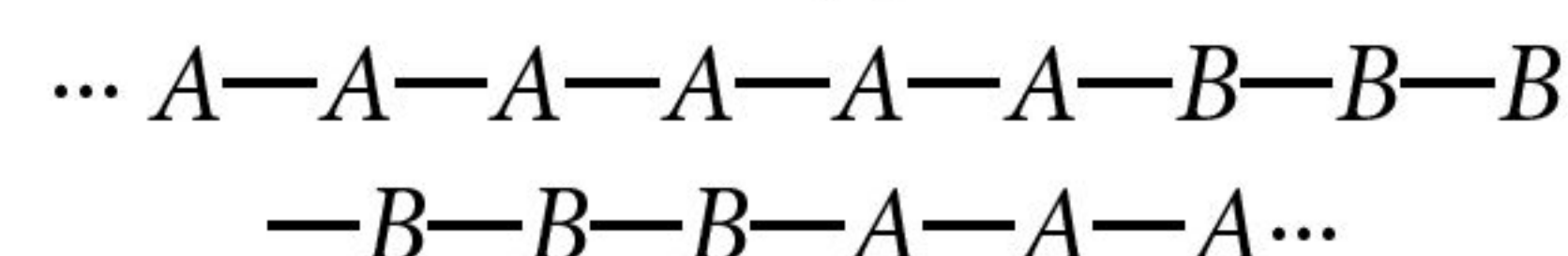
- **Alternating copolymer** : The two monomer units (A and B) are linked in an alternate manner throughout the polymer chain.



- **Random copolymer** : The distribution of monomer units is random throughout the chain.

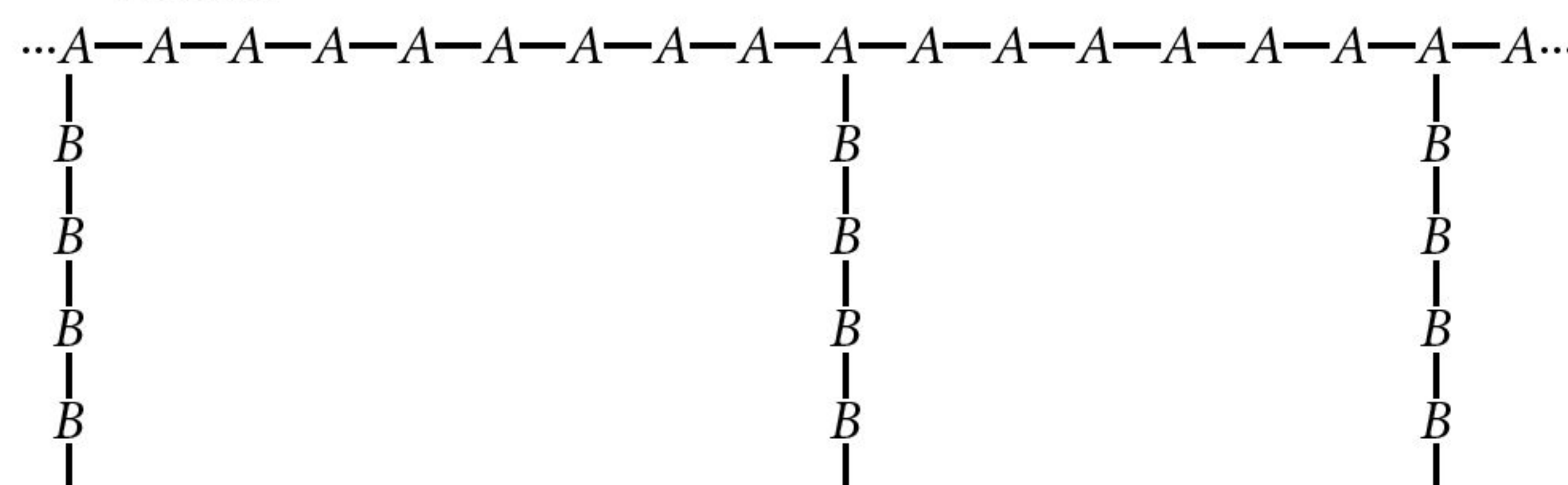


- **Block copolymer** : In this kind, there are blocks of each kind of monomer units ; *i.e.*, it consists of blocks of one types of monomer units alternate with blocks of another type.



Block copolymer can be prepared by initiating the radical polymerisation of one monomer to given homopolymer chains, following by addition of an excess of the second monomer.

- **Graft copolymer** : It consists of a linear polymer chain of one type to which has been grafted side-chains (branches) of another type of monomer units.



The formation of graft copolymer can be brought about by either of the two general methods:

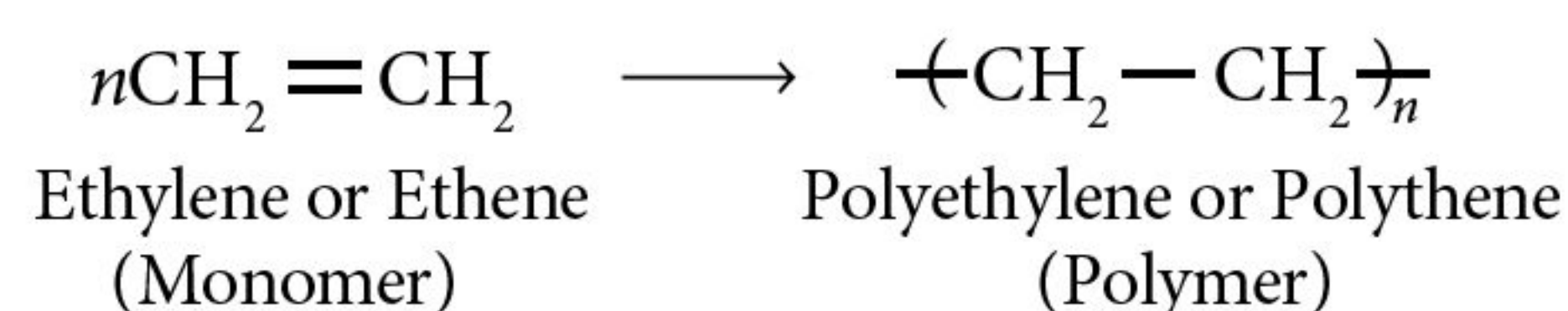
- Initiation of chain growth of monomer (B) on an existing polymer molecule formed from monomer (A) or
- Termination of chain growth of polymer (B) by an existing polymer molecule formed from monomer (A).

Classification on the Basis of Mode of Polymerisation

1. Addition polymers

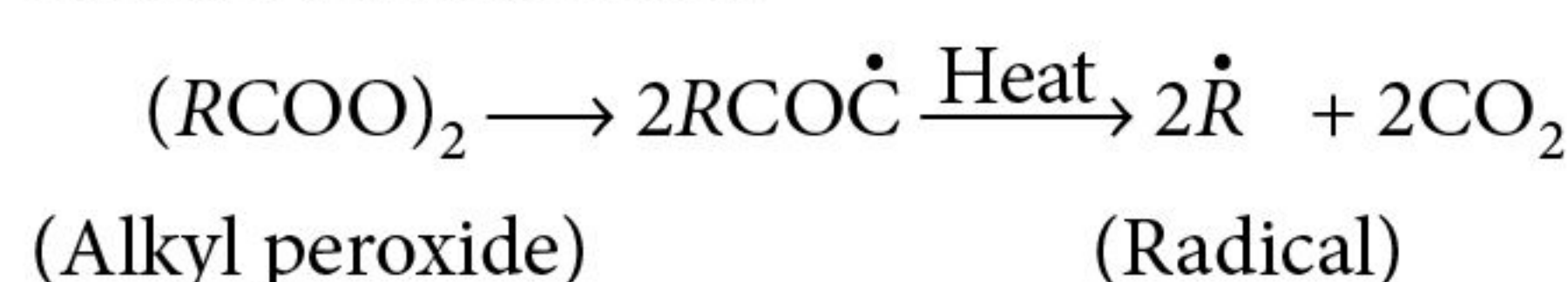
These are polymers formed by the addition of the molecules of the monomers without loss of molecules like H_2O , NH_3 , etc. The process of the formation of addition polymers is termed addition polymerisation.

The monomers of these polymers are unsaturated compounds and polymerisation involves successive additions across the double or triple bonds. *e.g.*, ethene and derivatives of ethene. These are also called chain growth polymers since they are formed by successive addition of monomer molecules to the growing chain carrying a reactive intermediate such as free radical, carbocation or carbanion.

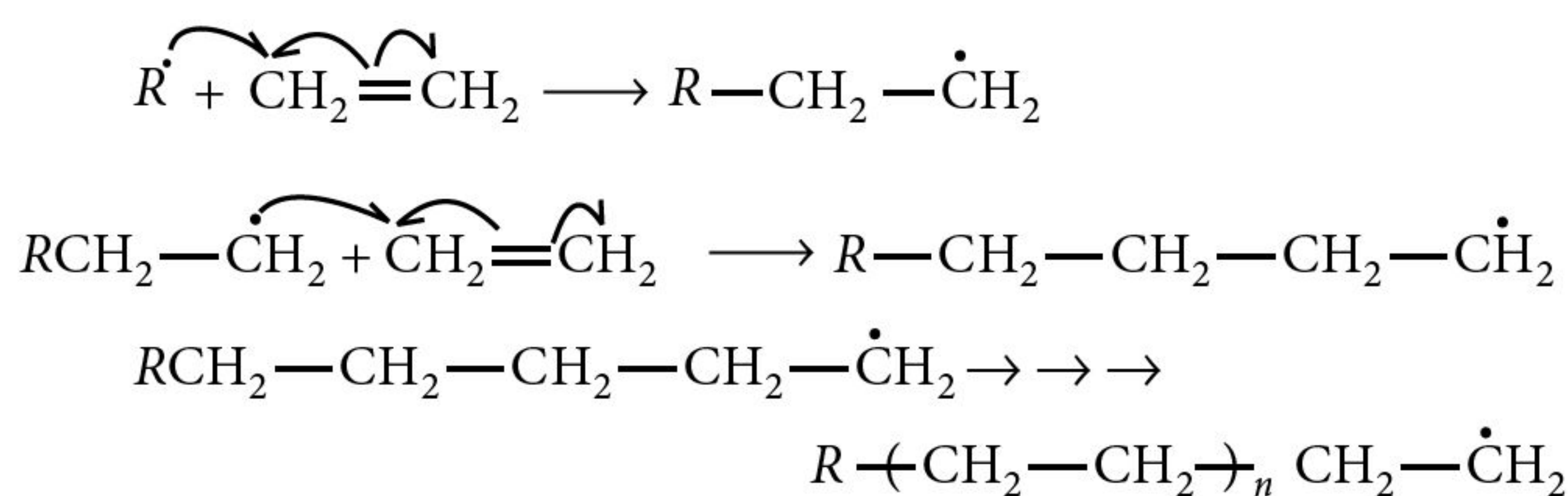


(a) Mechanism of free radical polymerisation : This is initiated by organic peroxides or by light. Steps involved are :

- **Chain initiation :**

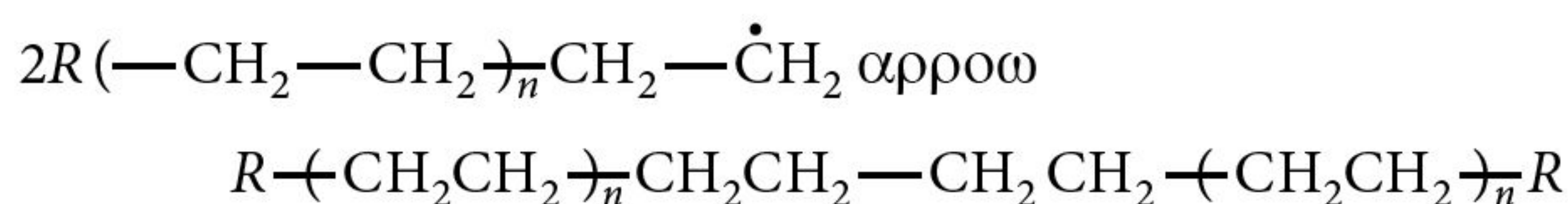


- **Chain propagation :**

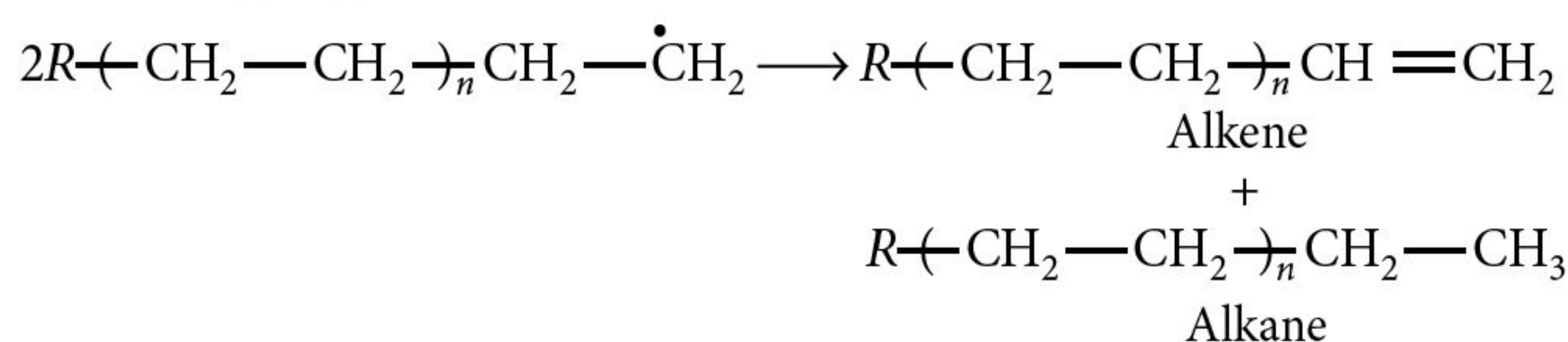


- **Chain termination :**

Combination :



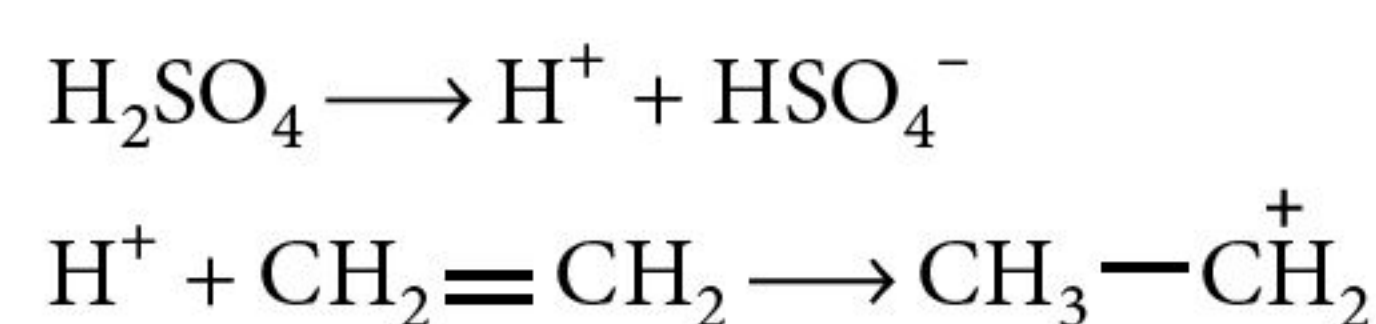
Disproportionation :



Polythene, polystyrene etc. are formed through this process.

(b) Mechanism of cationic addition polymerisation :
Initiated by the use of strong Lewis acids such as

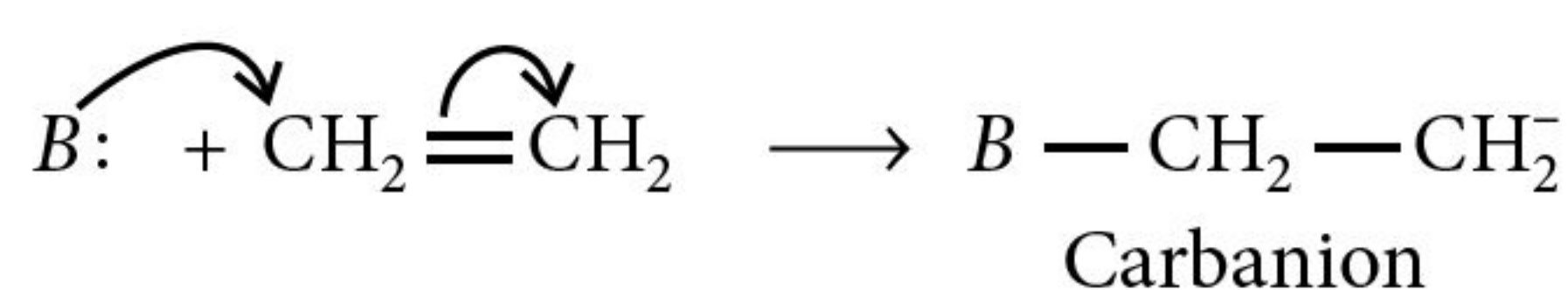
HF, AlCl₃, H₂SO₄, etc.



The carbocation thus formed undergoes addition with several monomers and finally the chain is terminated by combination with a negative ion or loss of a proton. Polyvinyl ether, polyisobutylene, etc. are formed through this process.

(c) Mechanism of anionic addition polymerisation :

Initiated by strong bases such as Na⁺NH₂⁻, C₄H₉Li and Grignard reagent, etc.



The carbanion thus so formed undergoes addition with number of monomers and finally terminates, *e.g.*, polymerisation of acrylonitrile, styrene and methyl methacrylate, etc.

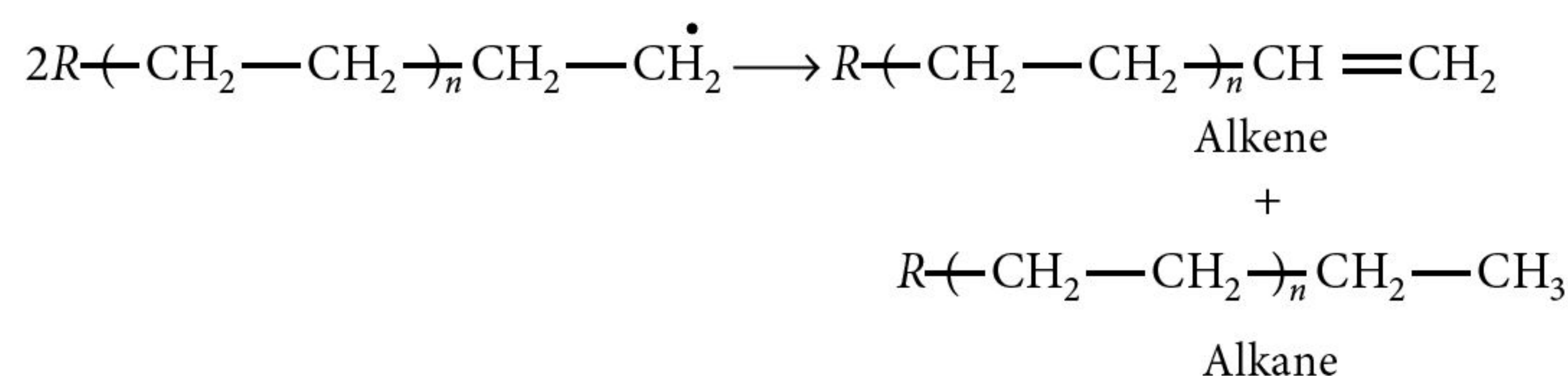
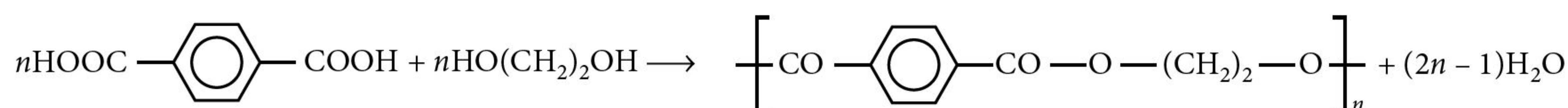
Homopolymers and copolymers

On the basis of monomer units, addition polymers are of two type :

- Addition polymer formed from only one type of monomer is called homopolymer, *e.g.*, polyethene, PVC, polyacrylonitrile, etc.
- Addition polymer formed from two or more different monomers is called copolymer, *e.g.*, Buna-N, Buna-S etc.

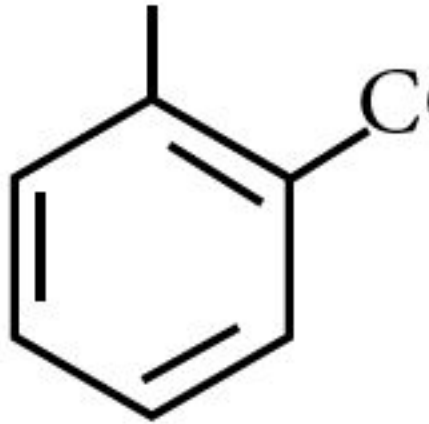
2. Condensation polymers

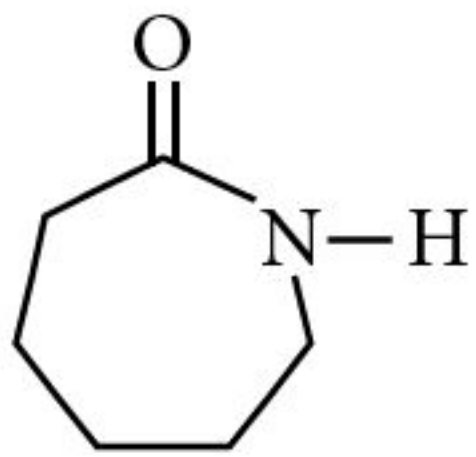
These are the polymers formed by the combination of two different bi-functional or tri-functional monomers with the elimination of simple molecules such as H₂O, NH₃, CO₂, HCl, R-OH, etc. This process of formation of polymers is also called step growth polymerisation. Condensation polymers are generally formed by reaction between polyfunctional monomers.



Some important homopolymers and copolymers

	Common name of the homopolymer	Monomer	Uses
1.	Polyethylene	$\text{CH}_2=\text{CH}_2$ Ethylene	In the manufacture of pipes, toys, bags, wire insulators, bottles, etc.
2.	Polyvinyl chloride (PVC)	$\text{CH}_2=\text{CHCl}$ Vinyl chloride	In the manufacture of sheets, water pipes, hoses, hand bags, etc.
3.	Polystyrene	$\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$ Styrene	In the manufacture of combs, toys, radio and television cabinets, etc.
4.	Polyacrylonitrile (PAN)	$\text{CH}_2=\text{CH}-\text{CN}$ Acrylonitrile	In the manufacture of orlon (fibre) and acrilon films.
5.	Teflon (Polytetrafluoro ethene, PTFE)	$\text{CF}_2=\text{CF}_2$ Tetrafluoro ethylene	In the manufacture of insulators, nonstick cookwares, gaskets, etc.
6.	Buna rubber	$\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$ 1,3-Butadiene	In the manufacture of tyres, hoses, etc.
7.	Polyvinyl acetate	$\text{CH}_2=\text{CHOCOCH}_3$ Vinyl acetate	In the manufacture of latex paint.

	Common Name of the Copolymer	Monomers	Uses
1.	Synthetic rubber or styrene butadiene rubber (SBR) or (Buna-S)	$\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$ Styrene $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$ 1, 3-Butadiene	In the manufacture of light duty tyres, belting, hoses and rubber soles.
2.	Dacron or Terylene	$\text{HOCH}_2-\text{CH}_2\text{OH}$ Ethylene glycol COOH  COOH (Terephthalic acid)	In the manufacture of fabrics and magnetic recording tapes.
3.	Glyptal	$\text{HOCH}_2-\text{CH}_2\text{OH}$ Ethylene glycol COOH  COOH Phthalic acid	In the manufacture of paints and lacquers.
4.	Nylon-6, 6	$\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ Hexamethylene diamine $\text{HOOC}(\text{CH}_2)_4\text{COOH}$ Adipic acid	In the manufacture of fabrics, tyre cords, ropes, carpets, etc.
5.	Bakelite	HCHO Formaldehyde $\text{C}_6\text{H}_5\text{OH}$ Phenol	In the manufacture of electrical goods, phonograph records, fountain pen barrels, combs, etc.

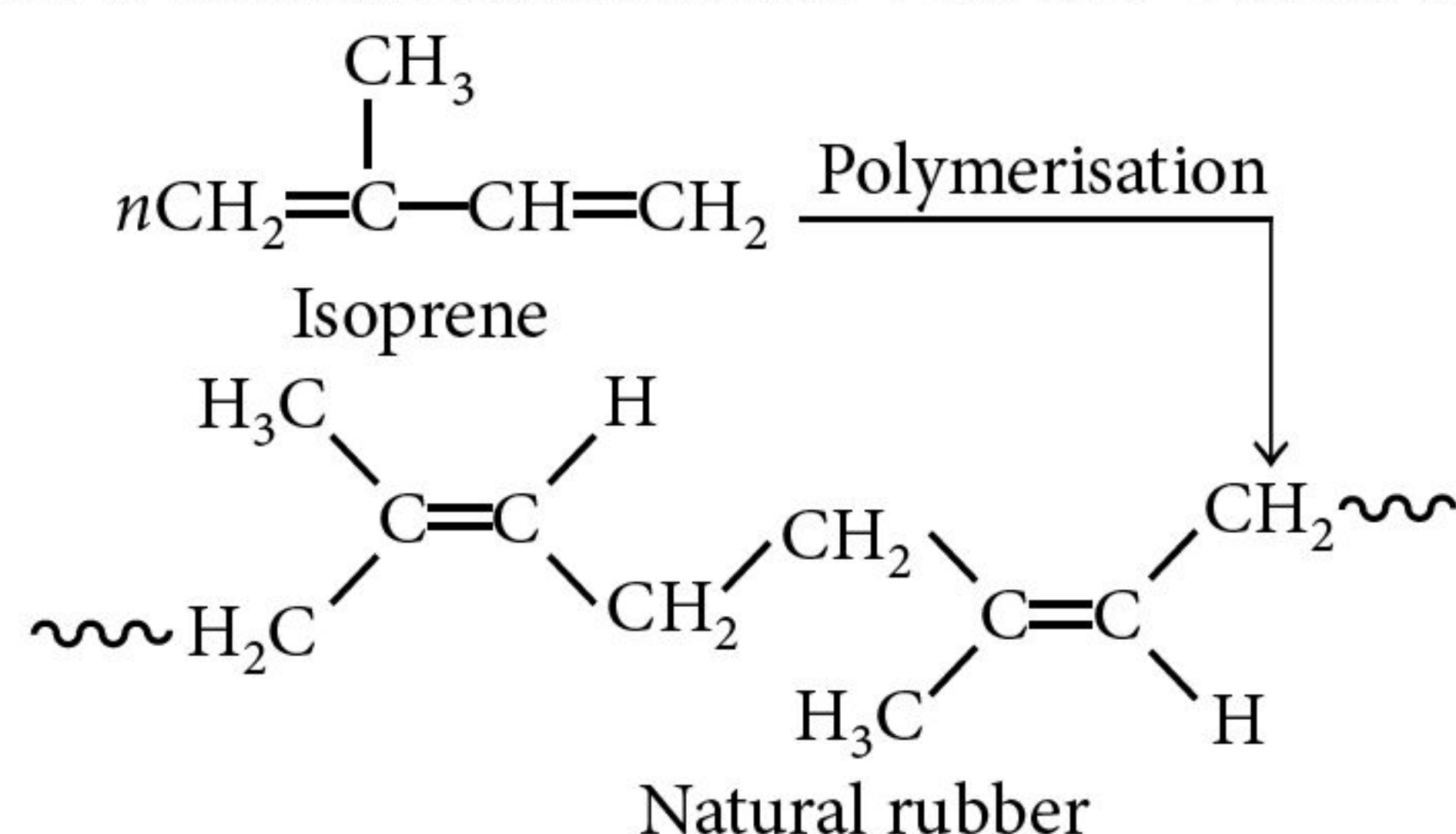
6.	Melamine-formaldehyde resin or Melamine	$\begin{array}{c} \text{HCHO} \\ \text{Formaldehyde} \\ \text{H}_2\text{N} \quad \text{N} \quad \text{NH}_2 \\ \diagdown \quad \diagup \\ \text{N} \quad \text{C} \quad \text{N} \\ \diagup \quad \diagdown \\ \text{NH}_2 \end{array}$ (Melamine)	In the manufacture of plastic crockery. They are quite hard and durable.
7.	Polyurethane	$\begin{array}{c} \text{HOCH}_2\text{—CH}_2\text{OH} \\ \text{Ethylene glycol} \\ \text{O}=\text{C}=\text{N—CH=CH—N}=\text{C}=\text{O} \\ \text{Ethylene di-isocyanate} \end{array}$	In the manufacture of fibres, paints and heat insulators.
8.	Nylon-6 $\left(\text{NH}-(\text{CH}_2)_5-\overset{\text{O}}{\parallel}{\text{C}} \right)_n$	 Caprolactam	In making fibres, plastics, tyre cords and ropes.

Natural rubber

It is a linear 1,4-addition polymer of isoprene and have *cis*-configuration of all double bonds thus, known as *cis*-1,4-polyisoprene.

Properties :

- It is insoluble in water, dilute acids and alkalies but soluble in organic solvents like benzene, petrol, etc.
- It has low elasticity and tensile strength.
- It has weak intermolecular van der Waals forces.

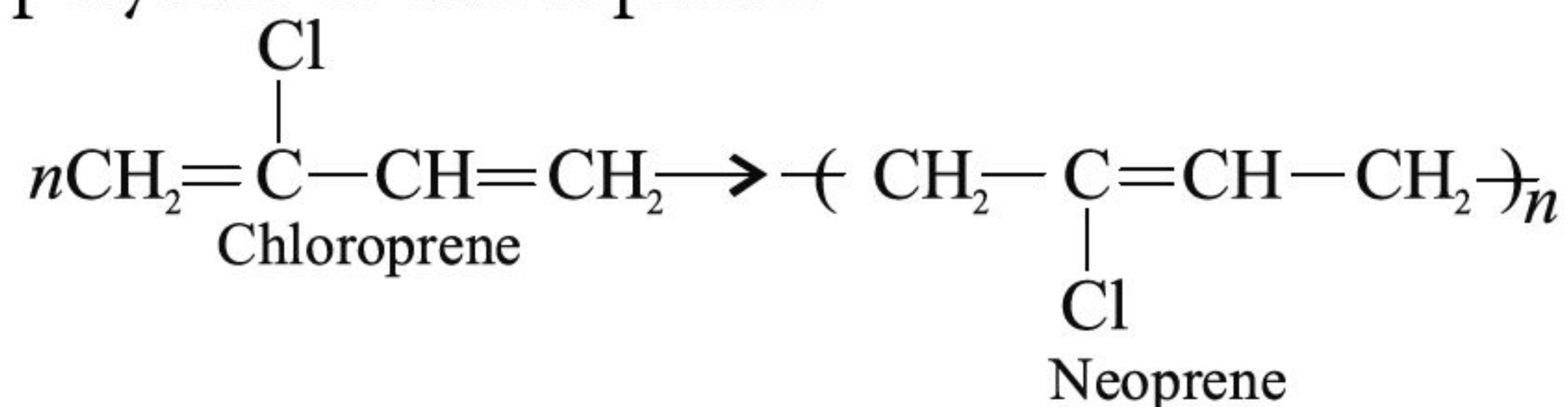


- Vulcanisation :** Vulcanisation is a process of treating natural rubber with sulphur at a temperature range of 373 to 415 K, to modify its properties. On vulcanisation, sulphur forms cross links at the reactive sites of the double bonds and gives mechanical strength to the rubber. Some additives like carbon black, zinc oxide, etc. are used to improve wearing properties.

Synthetic Rubber

Rubber prepared in laboratory is called synthetic rubber. e.g. Neoprene, Thiokol, buna-S and buna-N.

- Neoprene :** It was the first synthetic rubber. It is polymer of chloroprene.



It is more strong and resistant to action of acids, alkalies, oils, gasoline, sunlight, O₃, O₂, etc. It is non-inflammable.

- Buna-S (Styrene-butadiene rubber or SBR) :** It is a co-polymer of butadiene and styrene. It is prepared by free radical addition polymerisation by heating the two alkenes with Na metal.
- Buna-N :** It is a co-polymer of butadiene and acrylonitrile.

BIODEGRADABLE POLYMERS

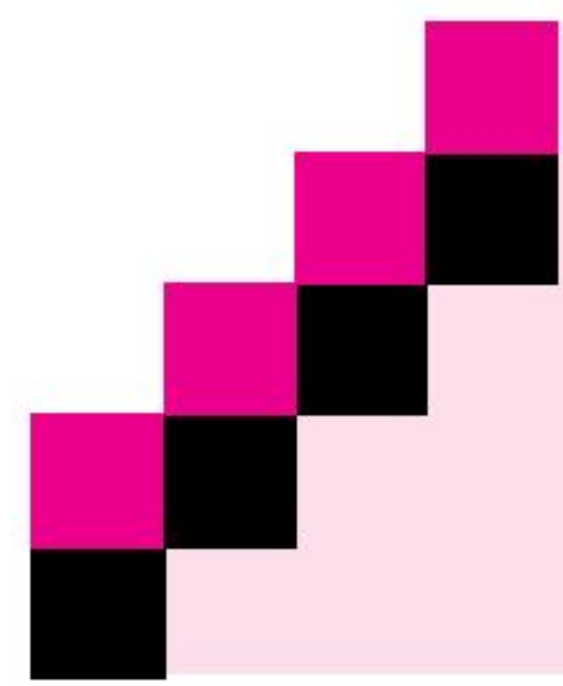
- Biopolymers disintegrate by enzymatic hydrolysis and to some extent by oxidation and hence are biodegradable.
- Synthetic polymers are non-biodegradable and hence create disposal problem. To overcome this, biodegradable synthetic polymers have been developed.

Poly-β-hydroxybutyrate-co-β-hydroxyvalerate (PHBV)

- It is a copolymer of 3-hydroxybutanoic acid and 3-hydroxypentanoic acid connected with ester linkages.
- Uses :** In speciality packaging, orthopaedic devices and in controlled drug release.

Nylon-2-nylon-6

- It is a step-growth polyamide copolymer of glycine and ε-aminocaproic acid.



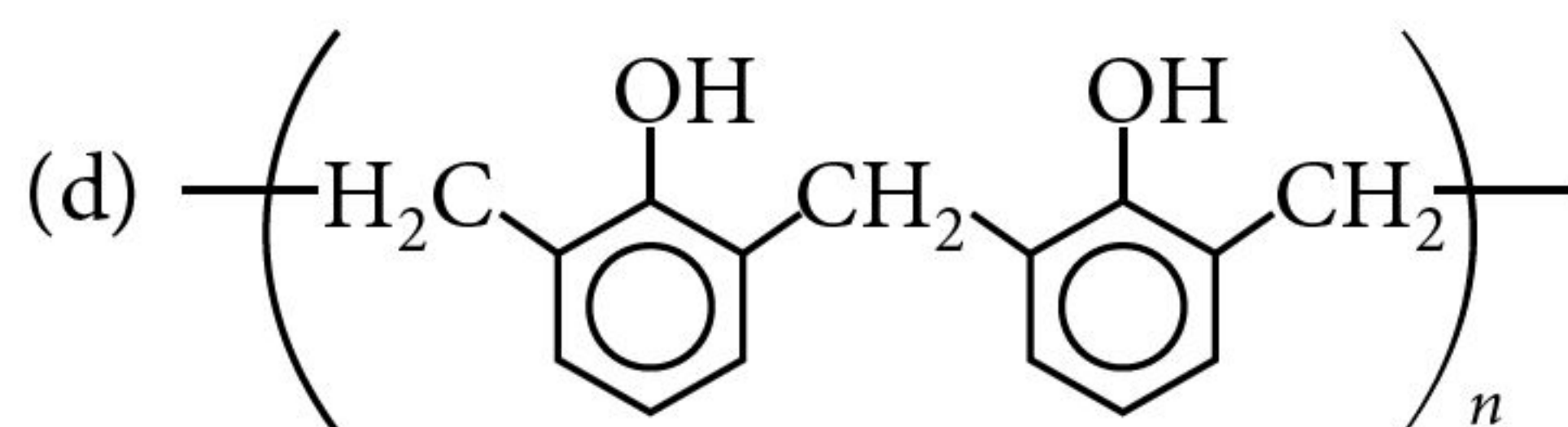
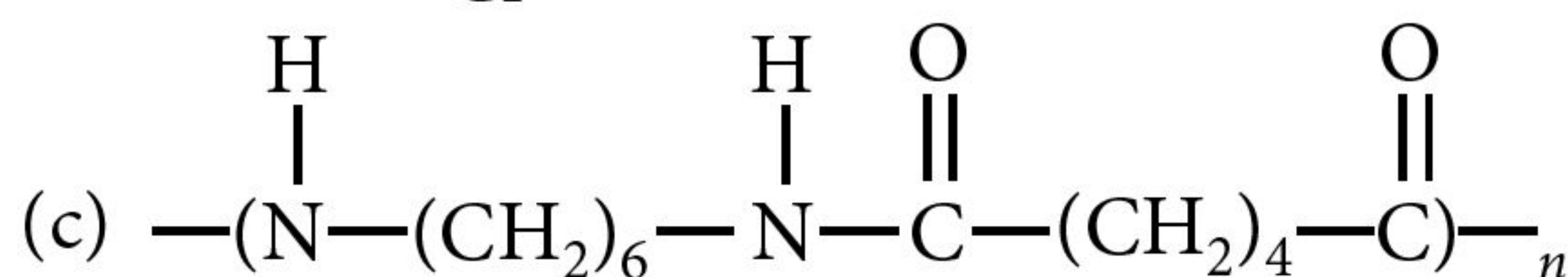
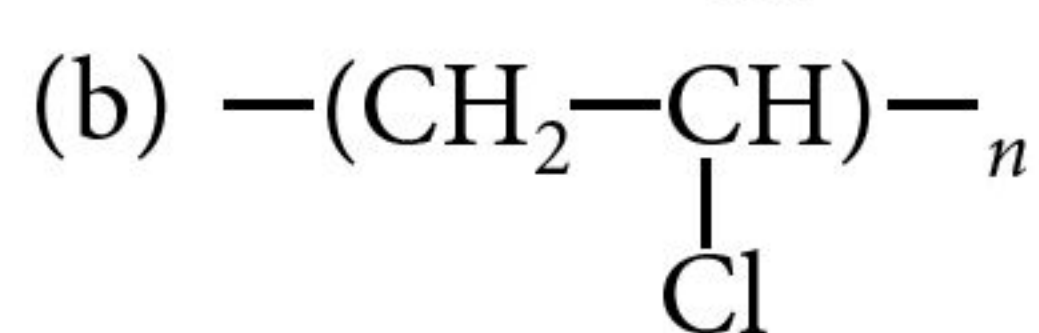
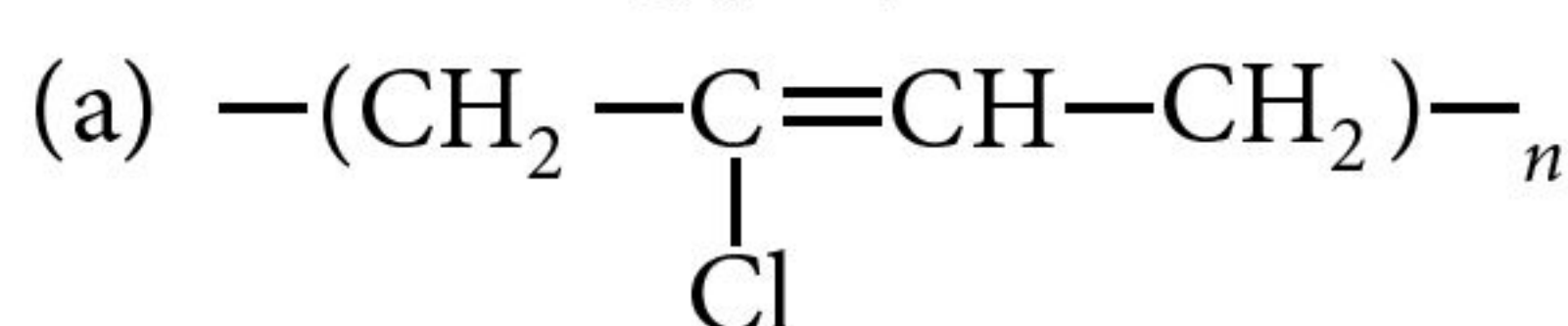
WRAP it up!

MULTIPLE CHOICE QUESTIONS

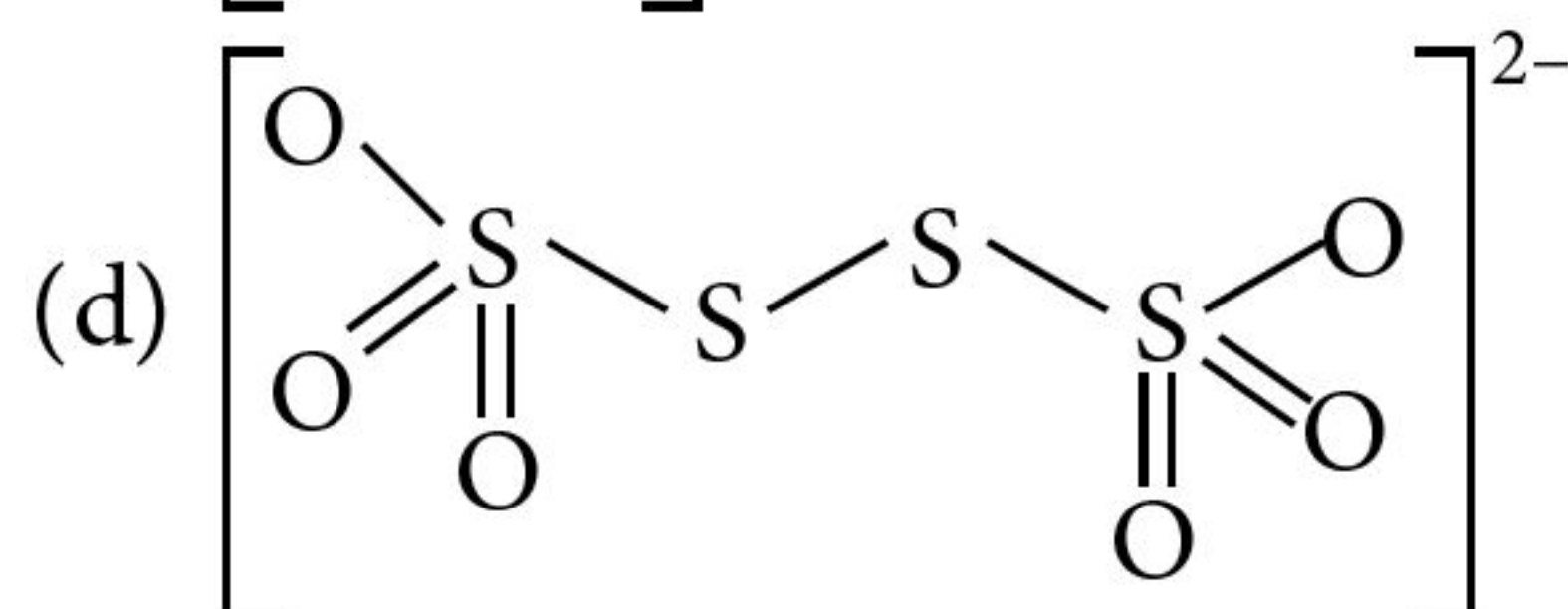
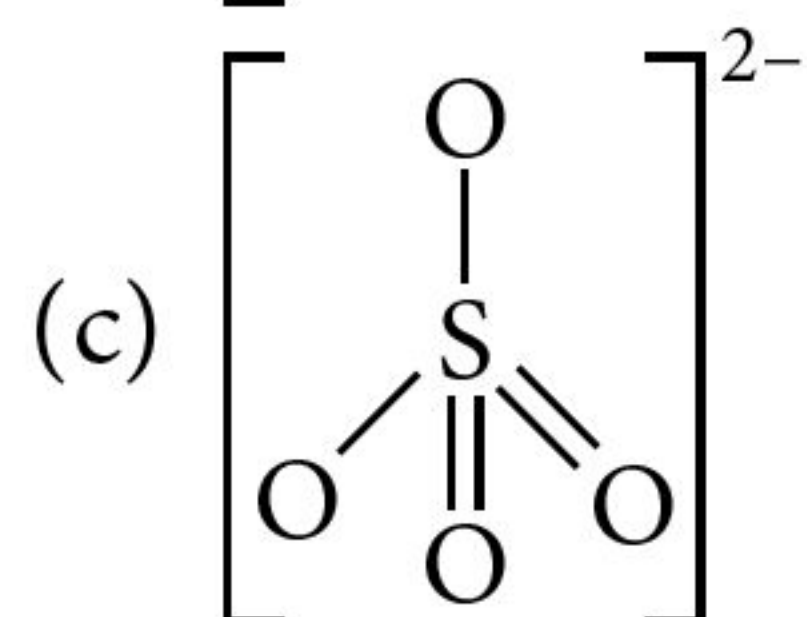
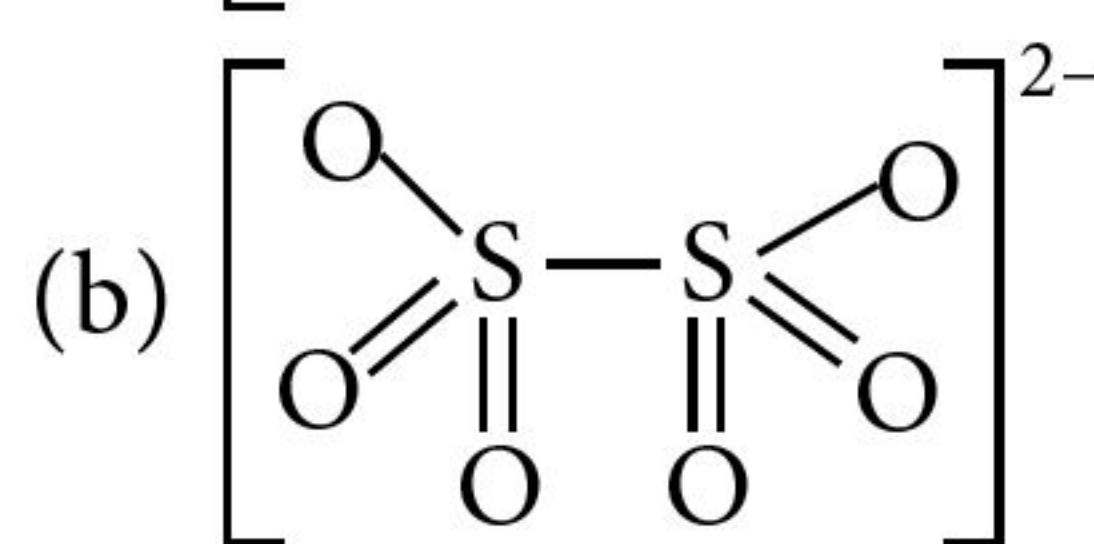
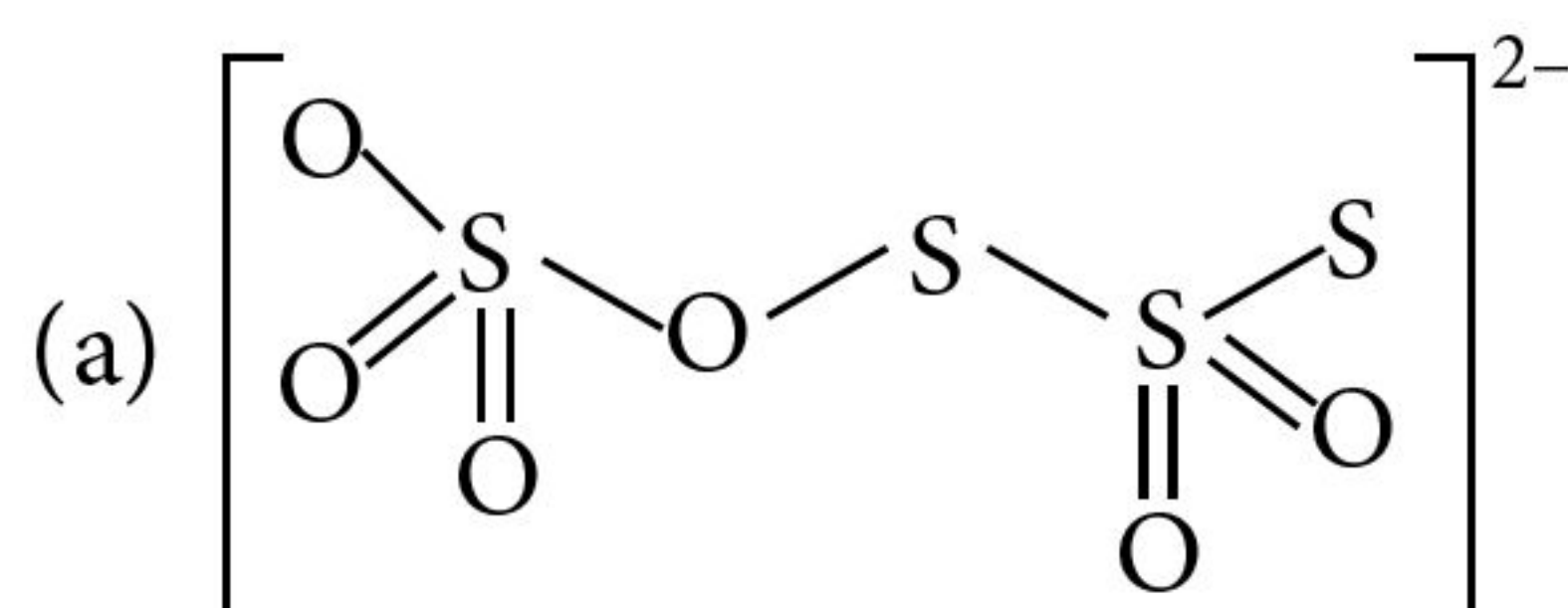
1. Among the oxides of nitrogen: N_2O_3 , N_2O_4 and N_2O_5 ; the molecule(s) having nitrogen-nitrogen bond is/are

- (a) N_2O_3 and N_2O_5 (b) N_2O_4 and N_2O_5
(c) N_2O_3 and N_2O_4 (d) only N_2O_5

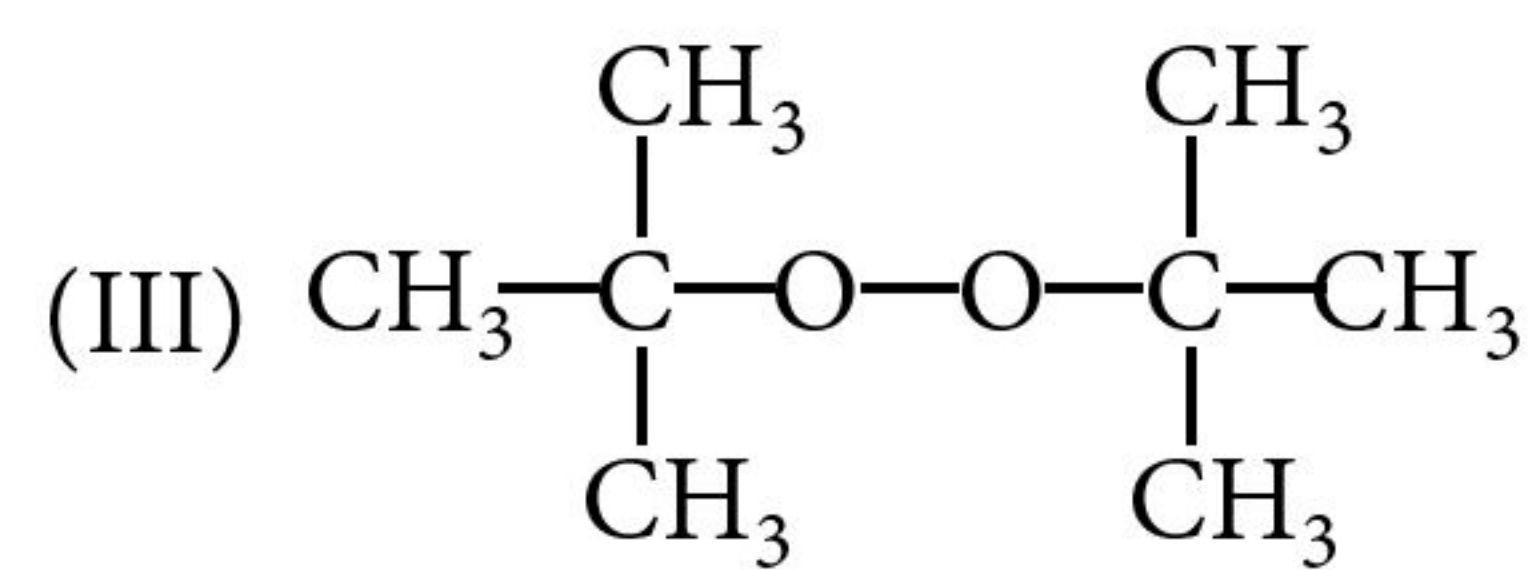
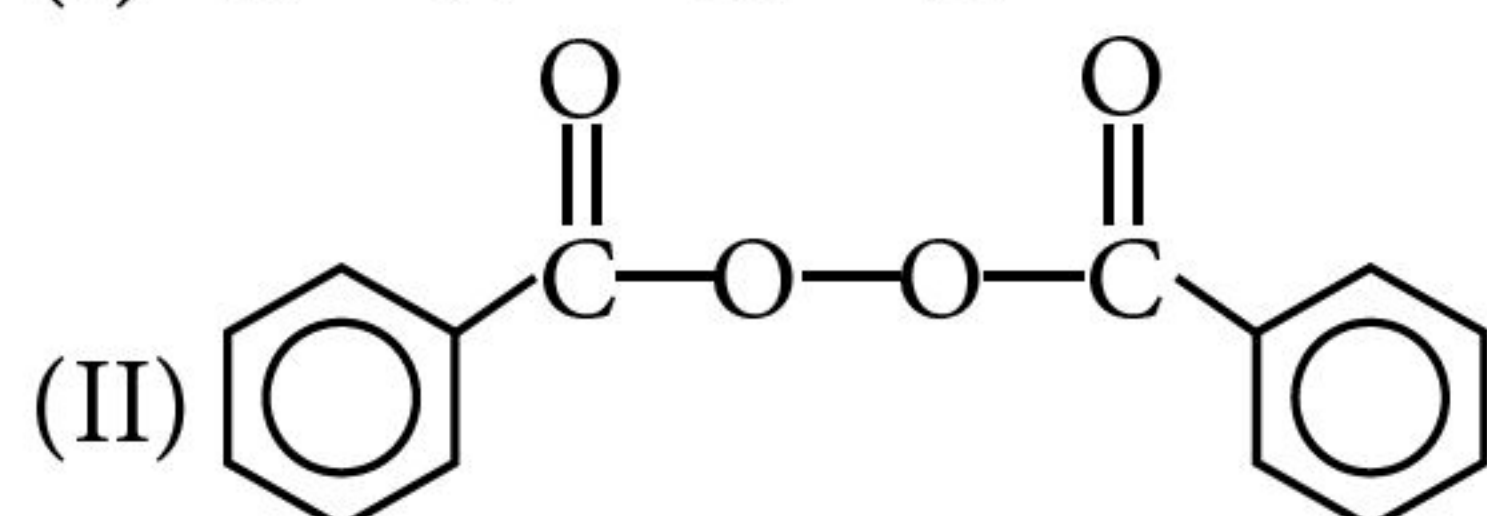
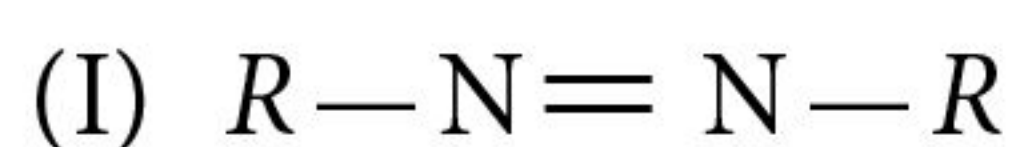
2. Which of the following is an example of thermosetting polymer?



3. The structure of dithionate ion is



4. Which of the following is radical initiator?



- (a) I only (b) II and III only
(c) I and III only (d) I, II and III

5. The decreasing order of the boiling points of the following hydrides is

(i) NH_3 , (ii) PH_3 , (iii) AsH_3 , (iv) SbH_3 , (v) H_2O

- (a) (v) > (iv) > (i) > (iii) > (ii)
(b) (v) > (i) > (ii) > (iii) > (iv)
(c) (ii) > (iv) > (iii) > (i) > (v)
(d) (iv) > (iii) > (i) > (ii) > (v)

6. Which of the following is correctly matched?

- I. PVC II. Polythene
III. Polyester IV. Polyacrylonitrile
V. Polystyrene



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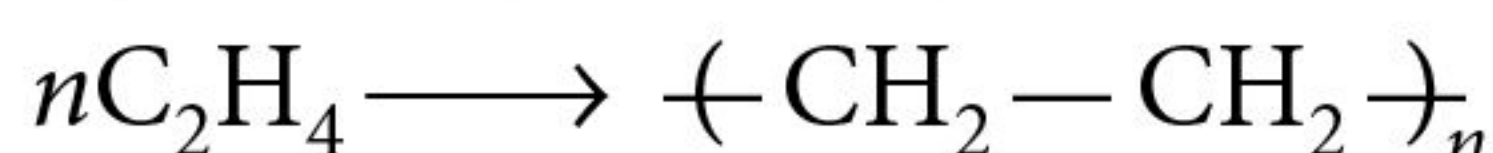
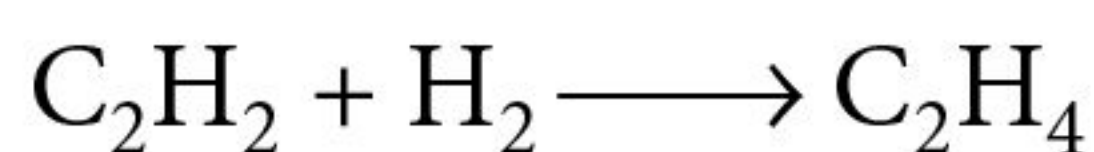
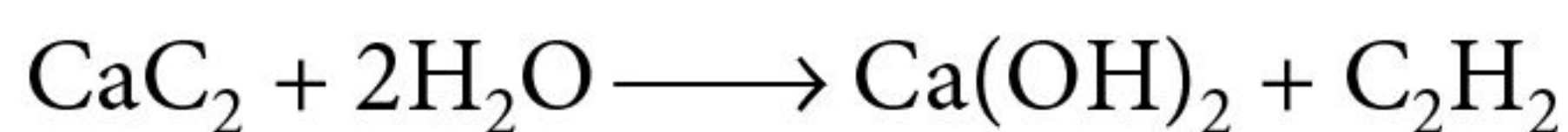
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Addition polymer Condensation polymer

- | | |
|------------------|--------------|
| (a) I, II | III, IV, V |
| (b) I, II, V | III, IV |
| (c) III | I, II, IV, V |
| (d) I, II, IV, V | III |

7. Polyethylene is obtained from calcium carbide.



Therefore, the amount of polyethylene obtained for 64 kg CaC_2 is

- (a) 7 kg (b) 14 kg (c) 21 kg (d) 28 kg

8. The compound that does not produce nitrogen gas by the thermal decomposition is

- (a) $\text{Ba(N}_3\text{)}_2$ (b) $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$
(c) NH_4NO_2 (d) $(\text{NH}_4)_2\text{SO}_4$

9. Match the column I with column II and mark the appropriate choice.

Column I		Column II	
(A)	Laughing gas	(P)	Hydrazoic acid
(B)	Anhydride of HNO_3	(Q)	Nitrous oxide
(C)	Acidic anhydride of HPO_3	(R)	Nitrogen pentoxide
(D)	Acidic hydride of nitrogen	(S)	Phosphorus pentoxide

- (a) A-P, B-Q, C-R, D-S (b) A-S, B-P, C-Q, D-R
(c) A-Q, B-R, C-S, D-P (d) A-R, B-S, C-P, D-Q

10. The monomers unit of PHBV is

- (a) 3-hydroxybutanoic acid and 3-hydropentanoic acid
(b) 3-hydroxybutanoic acid and 3-hydroxyhexanoic acid
(c) 3-hydroxyhexanoic acid and 3-hydroxyheptanoic acid
(d) 3-hydroxypropanoic acid and 3-hydroxybutanoic acid

11. The colour of halogens progressively deepens from fluorine to iodine because

- (a) halogens of higher atomic number absorb light of longer wavelength since the difference in energy between the frontier orbitals decreases as the atomic number increases
(b) fluorescence and phosphorescence become more intense as the atomic number of halogen increases

- (c) the standard electrode potential increases from I_2 to F_2
(d) halogens of higher atomic number absorb light of shorter wavelength since the difference in energy between the frontier orbitals increases as the atomic number increases.

12. Novolac on heating with formaldehyde undergoes _____ to form an infusible solid mass called _____.

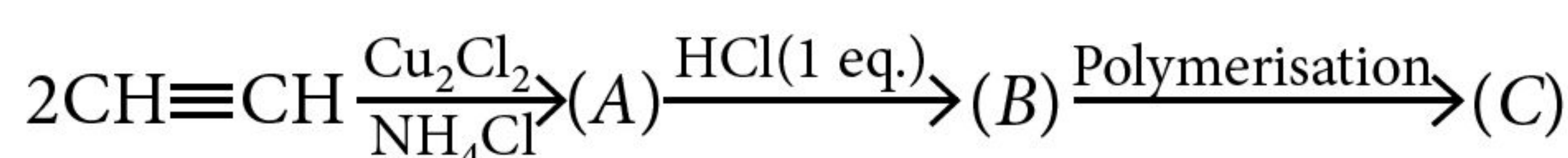
- (a) polymerisation, melamine
(b) vulcanisation, resin
(c) cross-linking, bakelite
(d) condensation, polystyrene

13. What can be concluded from the following table?

Halogen	Hypohalous acid	Halous acids	Halic acid	Perhalic acid
	(X = +1)	(X = +3)	(X = +5)	(X = +7)
Cl	HClO	HClO_2	HClO_3	HClO_4
Br	HBrO	–	HBrO_3	HBrO_4
I	HIO	–	HIO_3	HIO_4

- (a) From left to right thermal stability increases.
(b) From left to right basicity increases.
(c) From left to right covalent character remains same
(d) All of the above statements.

14. The polymer formed as result of following sequence of reactions is



- (a) Saran (b) PVC
(c) Neoprene (d) Chloroprene.

15. A greenish yellow gas reacts with an alkali hydroxide to form a halate which can be used in fireworks and safety matches. The gas and the halate are

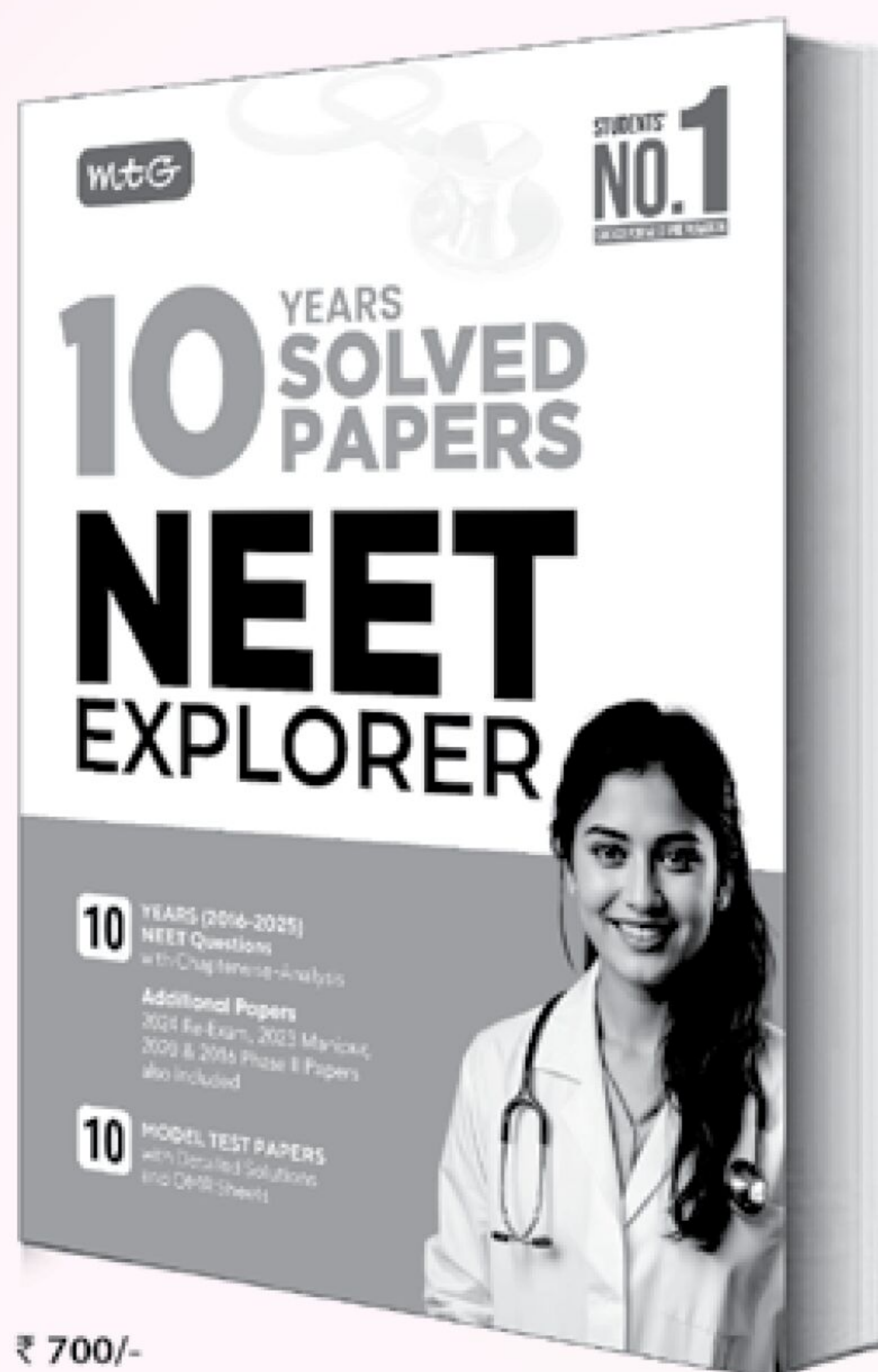
- (a) Br_2 , KBrO_3 (b) Cl_2 , KClO_3
(c) I_2 , NaIO_3 (d) I_2 , KIO_3

16. **Assertion :** Nylon-2, nylon 6 is a biodegradable polymer.

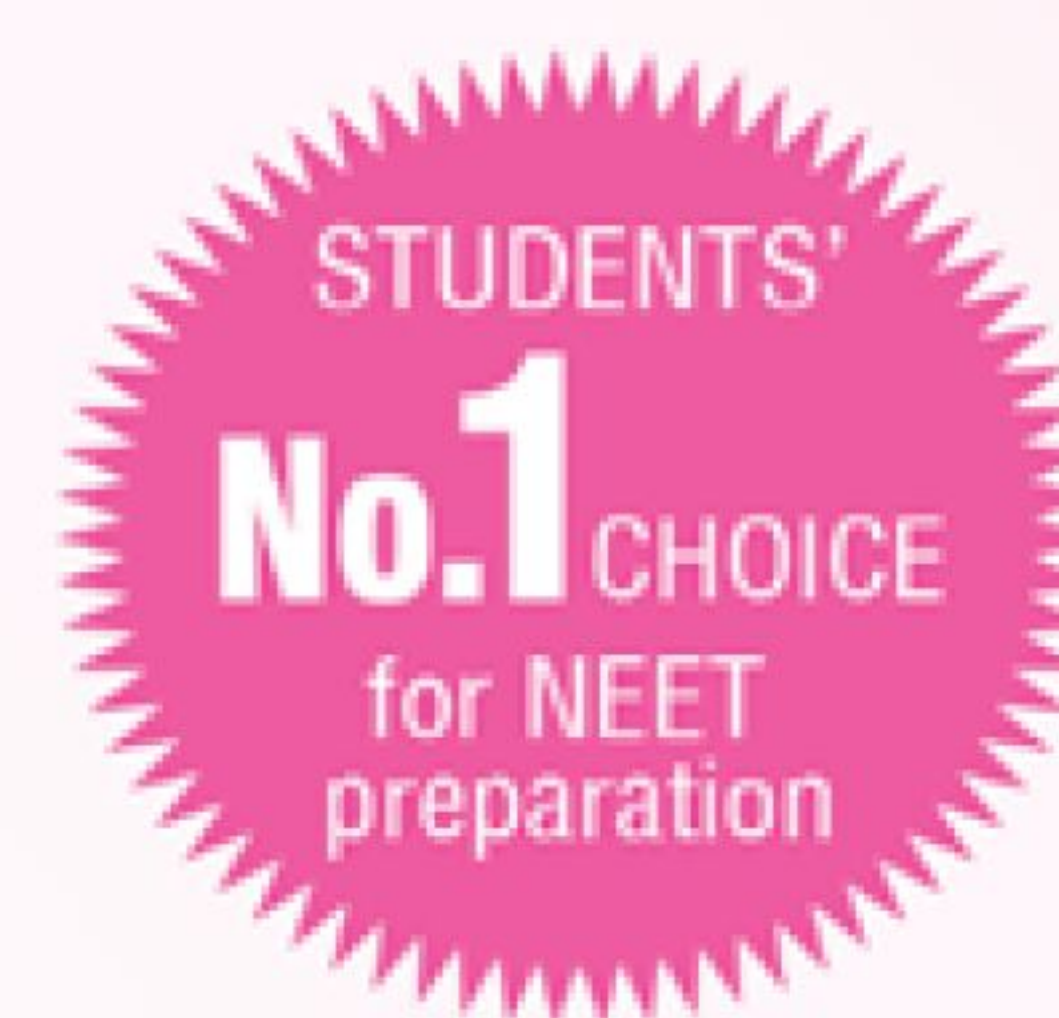
Reason : Nylon-2, nylon 6 is an alternating polyamide copolymer of 3-hydroxybutanoic acid and 3-hydroxy hexanoic acid.

- (a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

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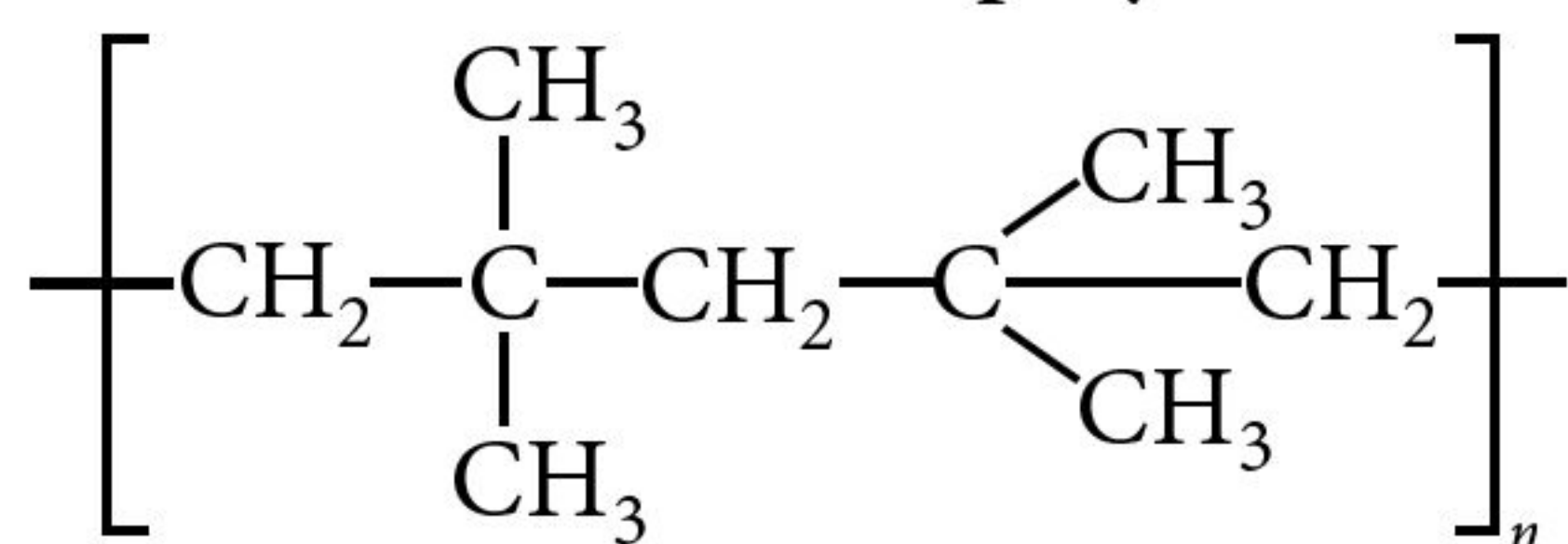
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17. The monomer of the polymer



- (a) $\text{H}_2\text{C}=\text{C}\begin{matrix} \nearrow \text{CH}_3 \\ \searrow \text{CH}_3 \end{matrix}$ (b) $\text{CH}_3\text{CH}=\text{CHCH}_3$
(c) $\text{CH}_3\text{CH}=\text{CH}_2$ (d) $(\text{CH}_3)_2\text{C}=\text{C}(\text{CH}_3)_2$

18. Hydrolysis of one mole of peroxodisulphuric acid produces

- two moles of sulphuric acid
- two moles of peroxomonosulphuric acid
- one mole of sulphuric acid and one mole of peroxo-monosulphuric acid
- one mole of sulphuric acid, one mole of peroxomonosulphuric acid and one mole of hydrogen peroxide.

19. Polymerisation of propene using Ziegler-Natta catalyst is advantageous over free radical polymerisation because

- (a) it can lead to living polymers *via* anionic polymerisation
- (b) it permits step-growth polymerisation resulting in a highly cross-linked polymer
- (c) it gives highly branched polymer with a high degree of crystallinity
- (d) it gives linear polymer molecules permitting stereochemical control.

20. Which of the following properties of the noble gases are correct?

- I. They readily form compounds which are colourless.
- II. They generally do not form ionic compounds.
- III. Xenon has variable oxidation states in its compounds.
- IV. The smaller He and Ne do not form clathrate compounds.

- (a) I, II, III
(b) II, III, IV
(c) I, III, IV
(d) All are correct.

NUMERICAL VALUE TYPE QUESTIONS

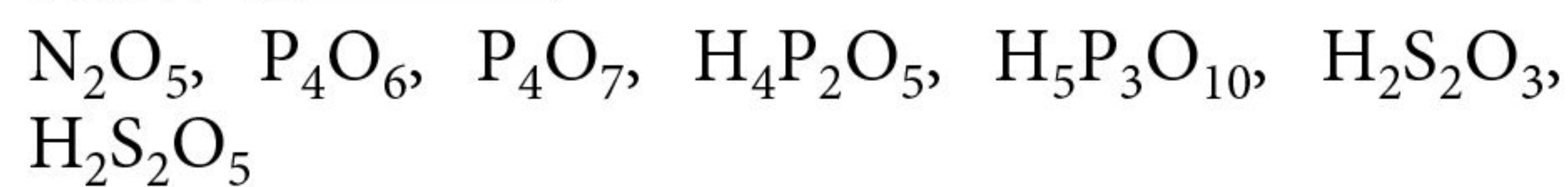
21. The number of polymers that contain isoprene as one of the monomers is _____.

Thiokol, Neoprene, Gutta-percha, Buna-S, SBR, Natural rubber, Nitrile rubber, Glyptal.

22. Among the following allotropic forms of sulphur, the number of allotropic forms, which will show paramagnetism is _____.

- (A) α -sulphur (B) β -sulphur
(C) S_2 -form

23. The total number of compounds having at least one bridging oxo group among the molecules given below is _____.



24. A compound 'X' reacts with formaldehyde to form a resin intermediate 'Y'. Polymerisation of this resin gives melamine polymer.

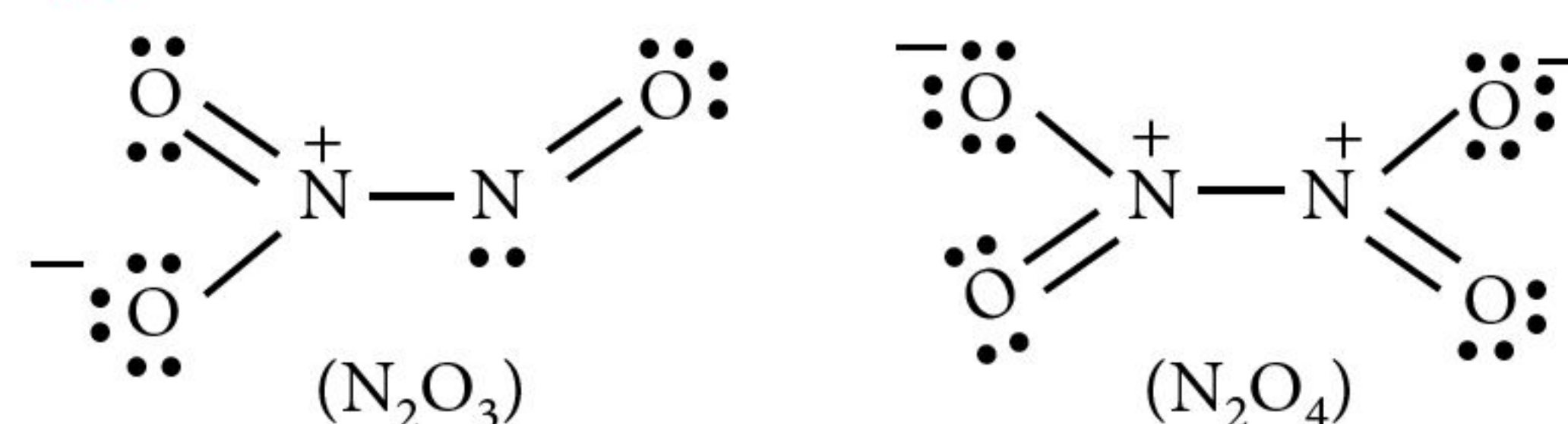
If p and q are number of carbon atoms, number of nitrogen atoms respectively in compound 'X' and r is the number of double bonds in compound 'X'

and 'Y'. The value of $\left(\frac{q+r}{p}\right)$ is _____.

25. The number of P–O–P bonds in cyclotrimetaphosphoric acid is _____.

SOLUTIONS

1. (c) : Structures of oxides of nitrogen are :



Thus, N_2O_3 and N_2O_4 contain one N — N bond.

2. **(d):** Novolac is a thermosetting polymer formed by condensation of phenol and formaldehyde.

3. (b)

4. (d)

5. (a): H_2O and NH_3 have abnormally high boiling point because of their tendency to form hydrogen bonds. NH_3 has higher boiling point than phosphine and then boiling point increases down the group because of increase in size.

$$\text{B.pt. : H}_2\text{O} > \text{SbH}_3 > \text{NH}_3 > \text{AsH}_3 > \text{PH}_3$$

6. (d): Polyester is a condensation polymer. PVC, polythene, polyacrylonitrile and polystyrene are addition polymers.

7. (d): Moles of $\text{CaC}_2 = \frac{64 \times 10^3}{64} \cong 1 \times 10^3$.

∴ From the balanced chemical equation,
moles of C_2H_2 = moles of C_2H_4

$$= \text{moles of CaC}_2 = 1 \times 10^3$$
$$\therefore \text{Moles of polythene} = \frac{1}{n} \times 1 \times 10^3$$
$$\therefore \text{Weight of polythene} = \frac{1}{n} \times 1 \times 28 n \text{ kg} = 28 \text{ kg}$$

8. (d)

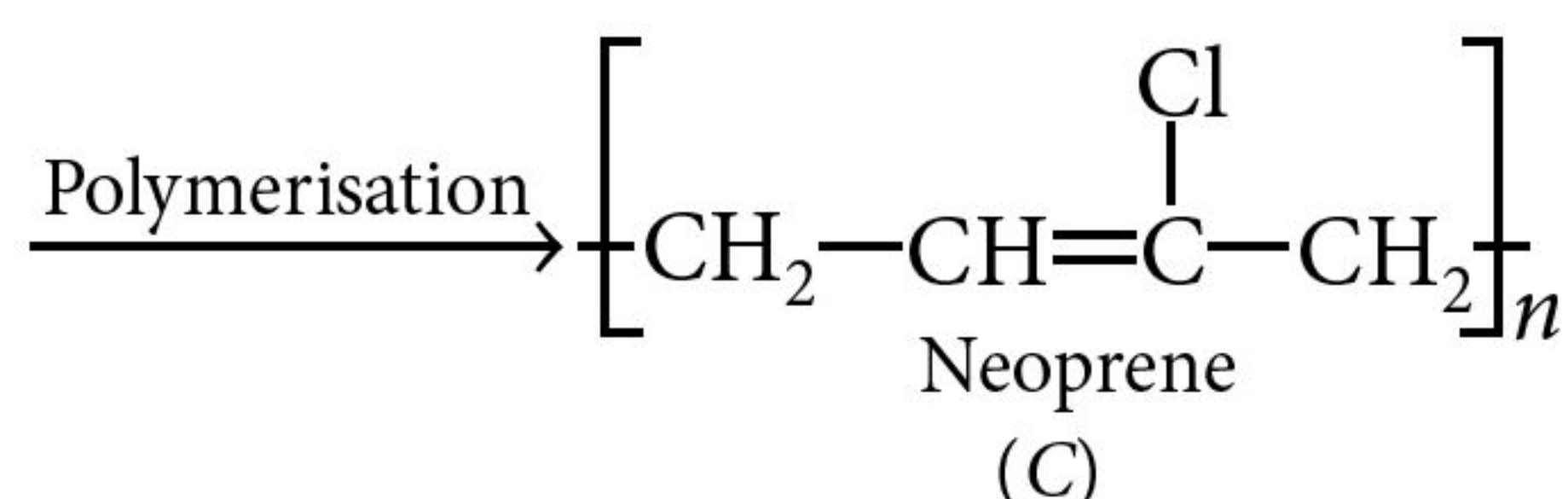
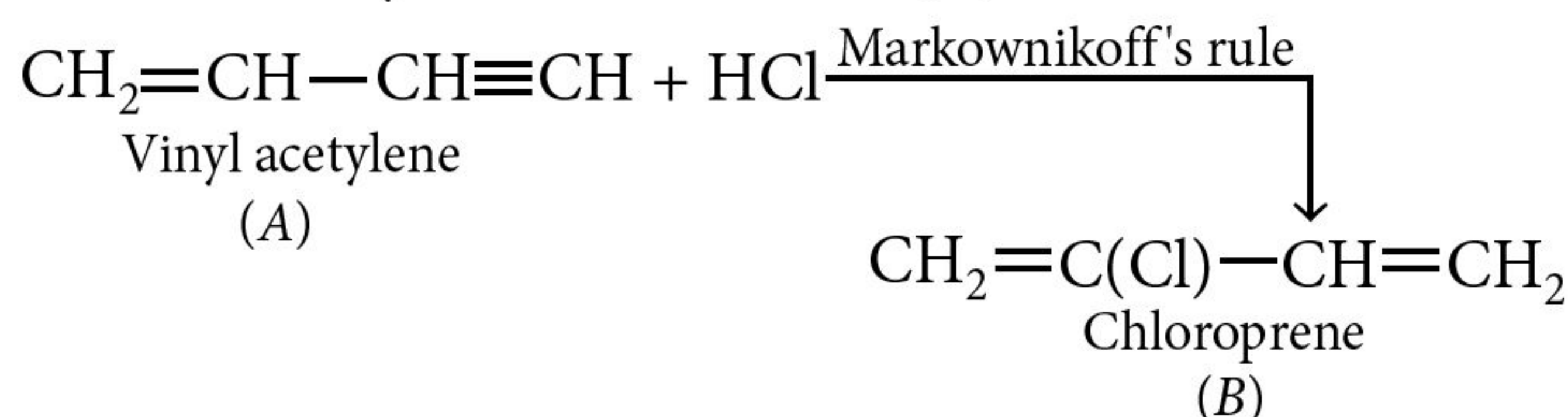
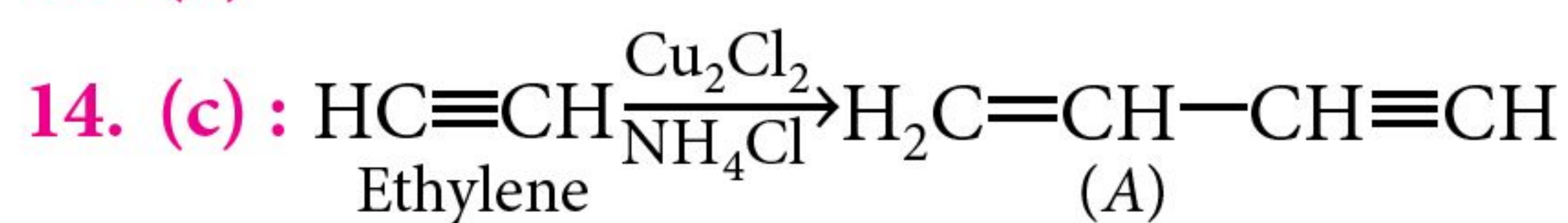
9. (c)

10. (a) : Poly- β -hydroxybutyrate-Co- β -hydroxyvalerate (PHBV) is a polymer of 3-hydroxypentanoic acid and 3-hydroxybutanoic acid.

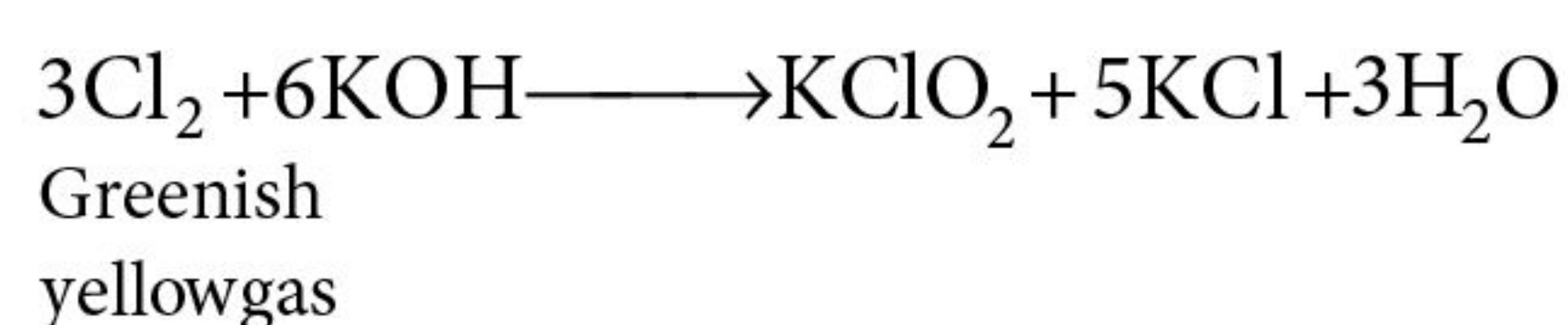
11. (a)

12. (c) : Novolac on heating with formaldehyde undergoes cross-linking to form bakelite.

13. (a)

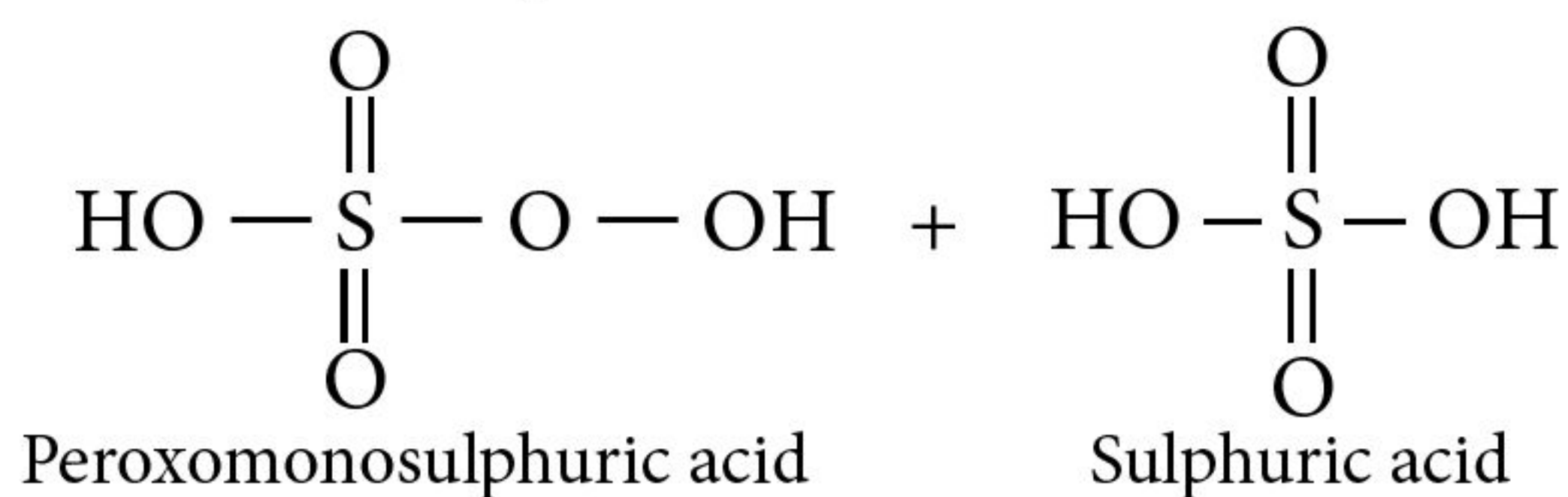
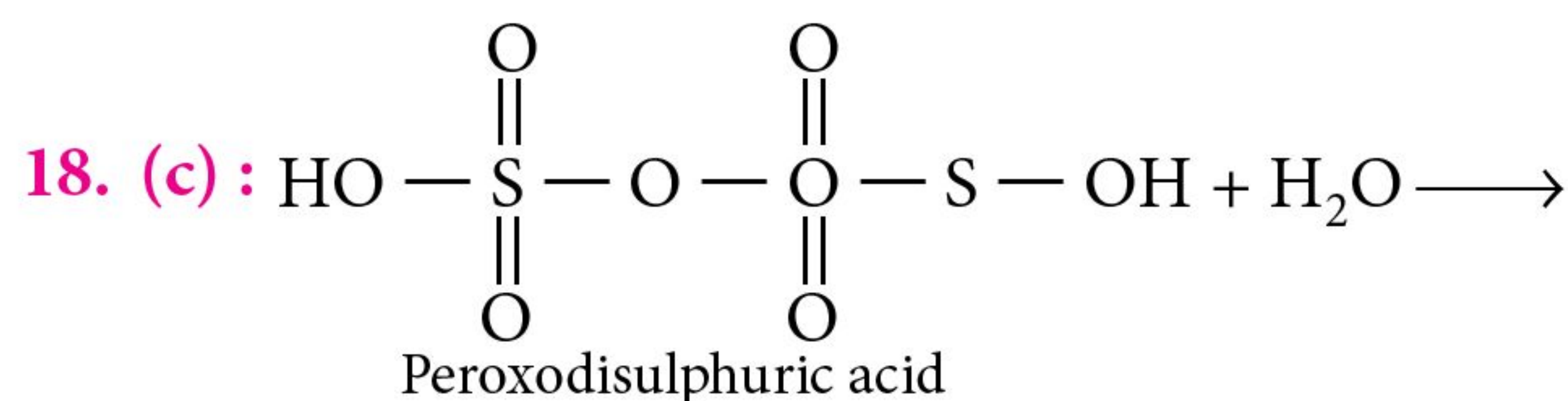
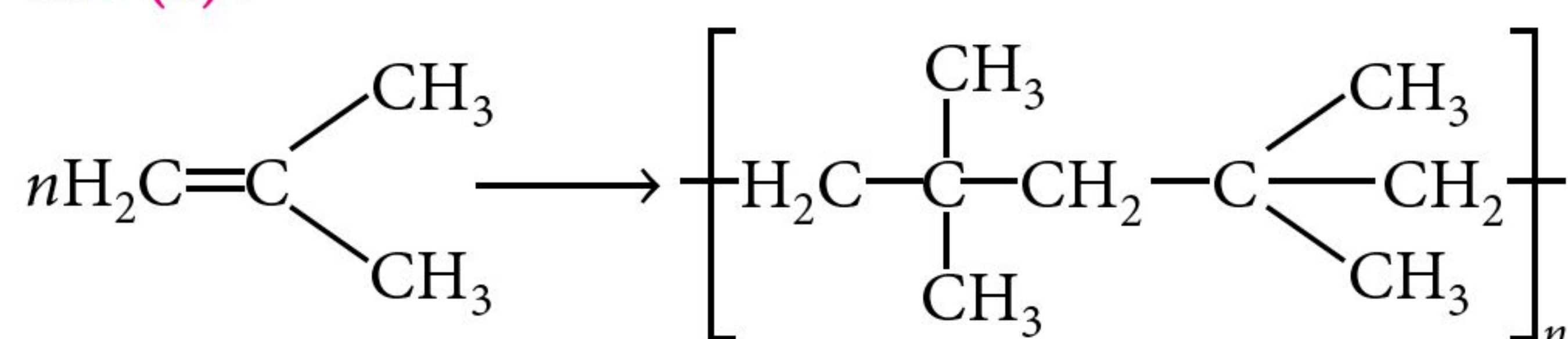


15. (b) : A halate will be formed from halogen and the greenish yellow gas is Cl_2 . The halate which is used in fireworks and safety matches is KClO_3 . The reaction involved is



16. (c) : Nylon-2, nylon 6 is a biodegradable polymer. Its monomeric units are glycine acid and amino caproic acid.

17. (a) :



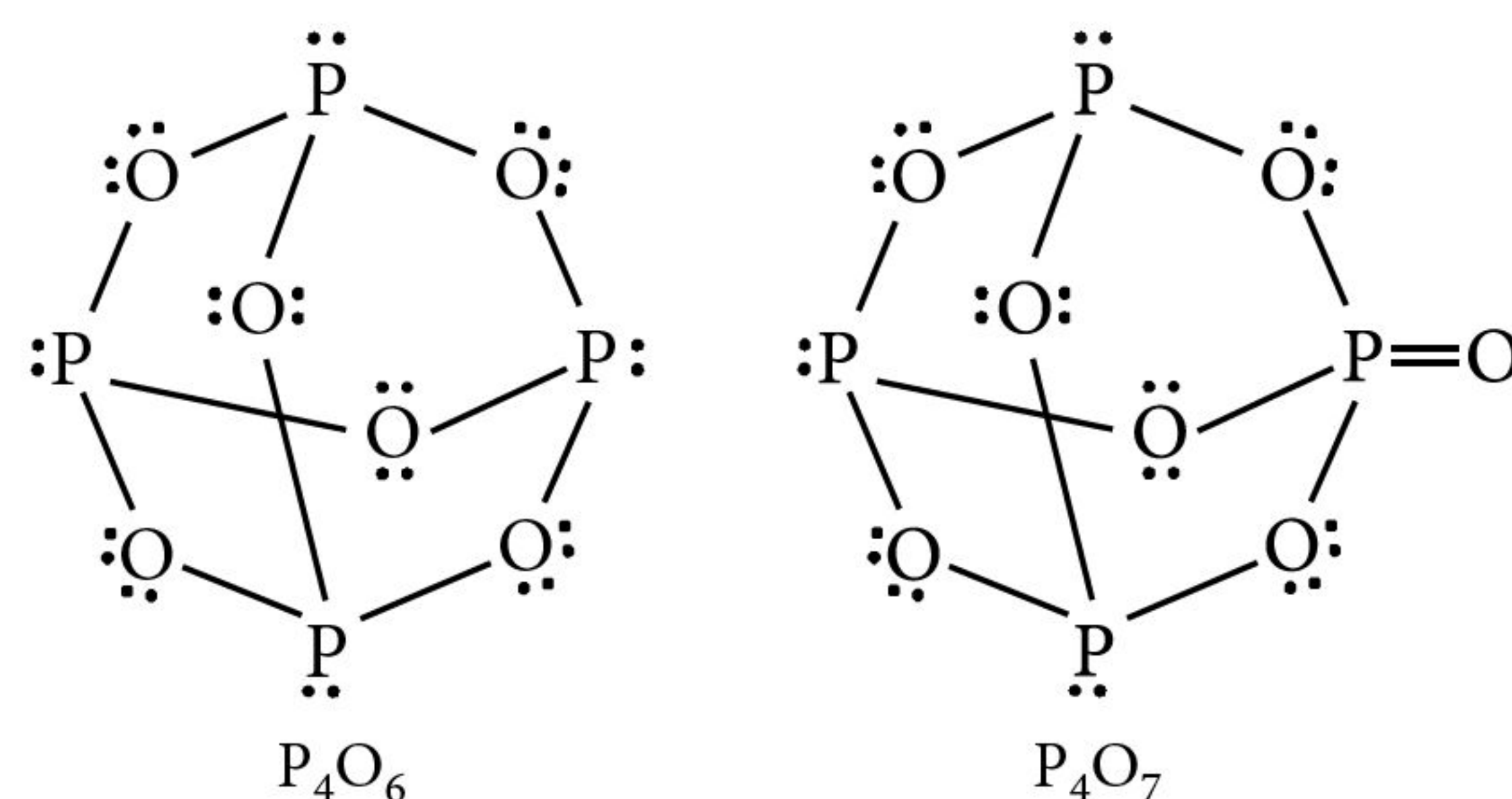
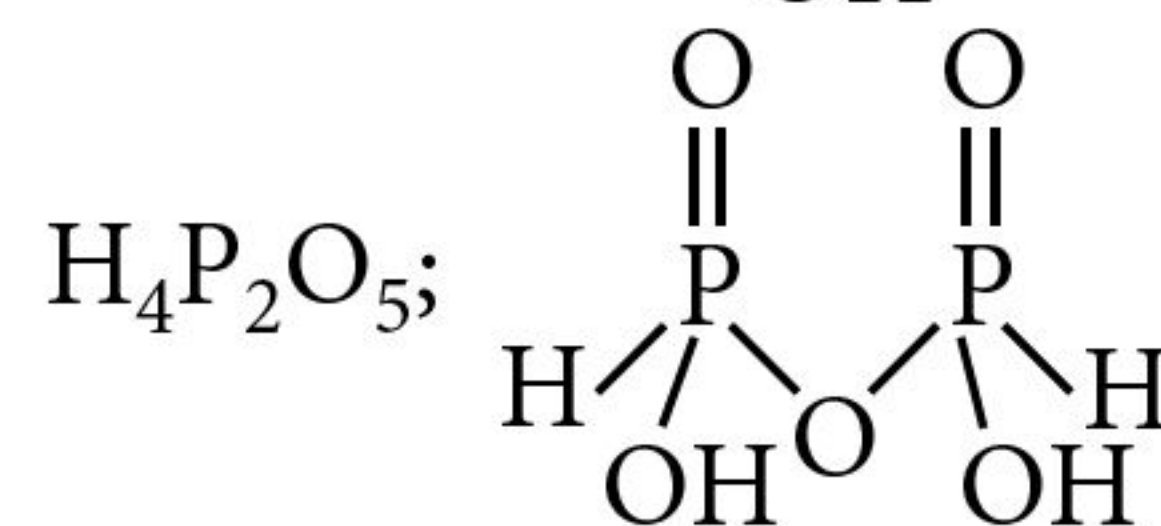
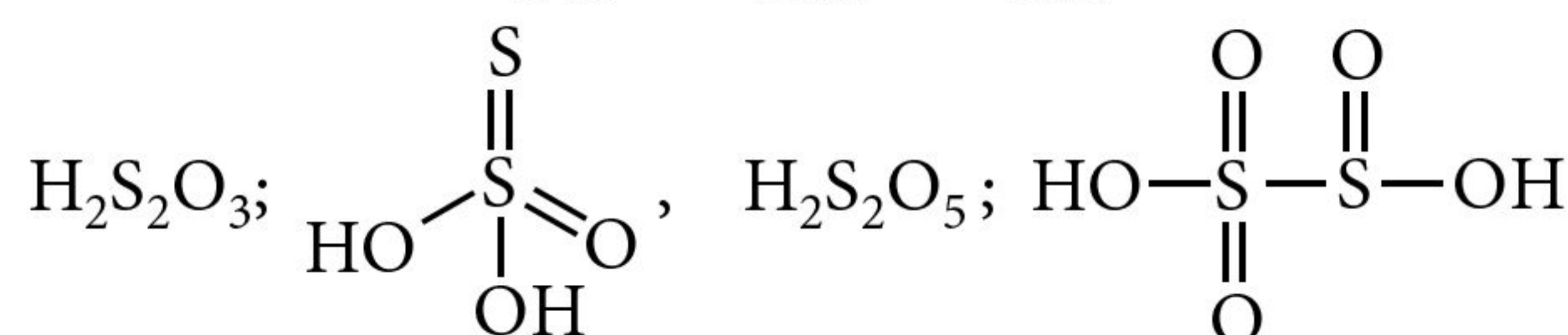
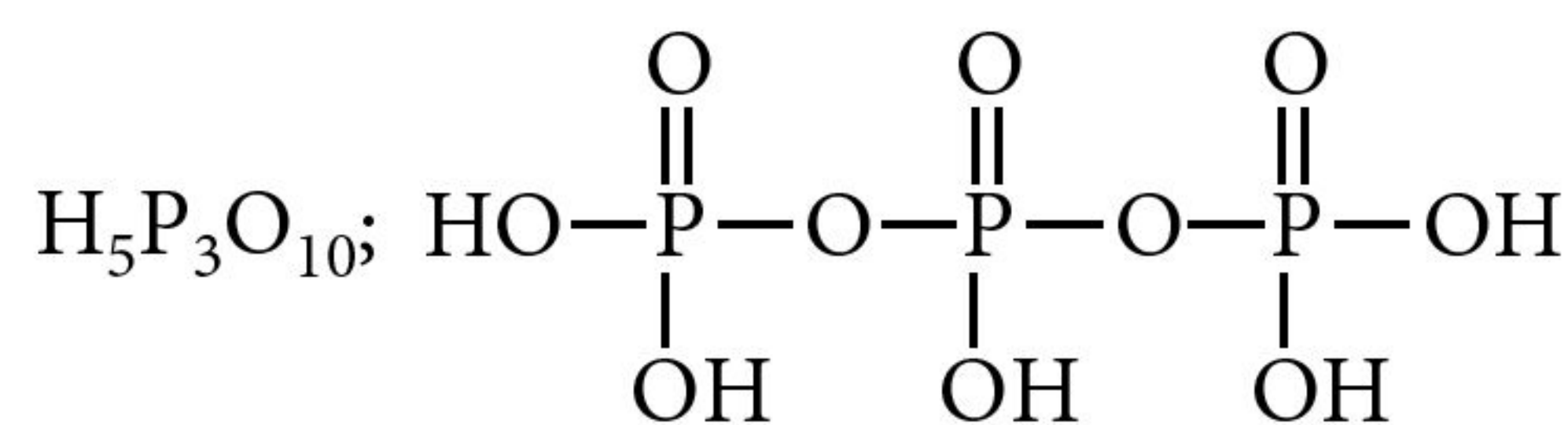
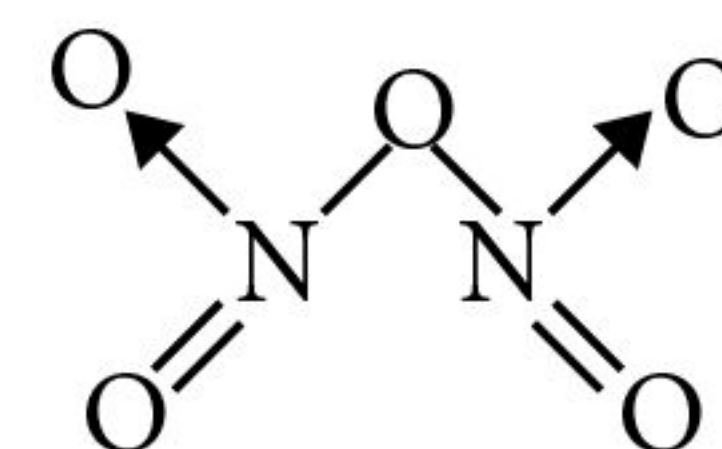
19. (d) : It gives linear polymer molecules permitting stereochemical control.

20. (b) : They do not form compounds readily as they are chemically inert.

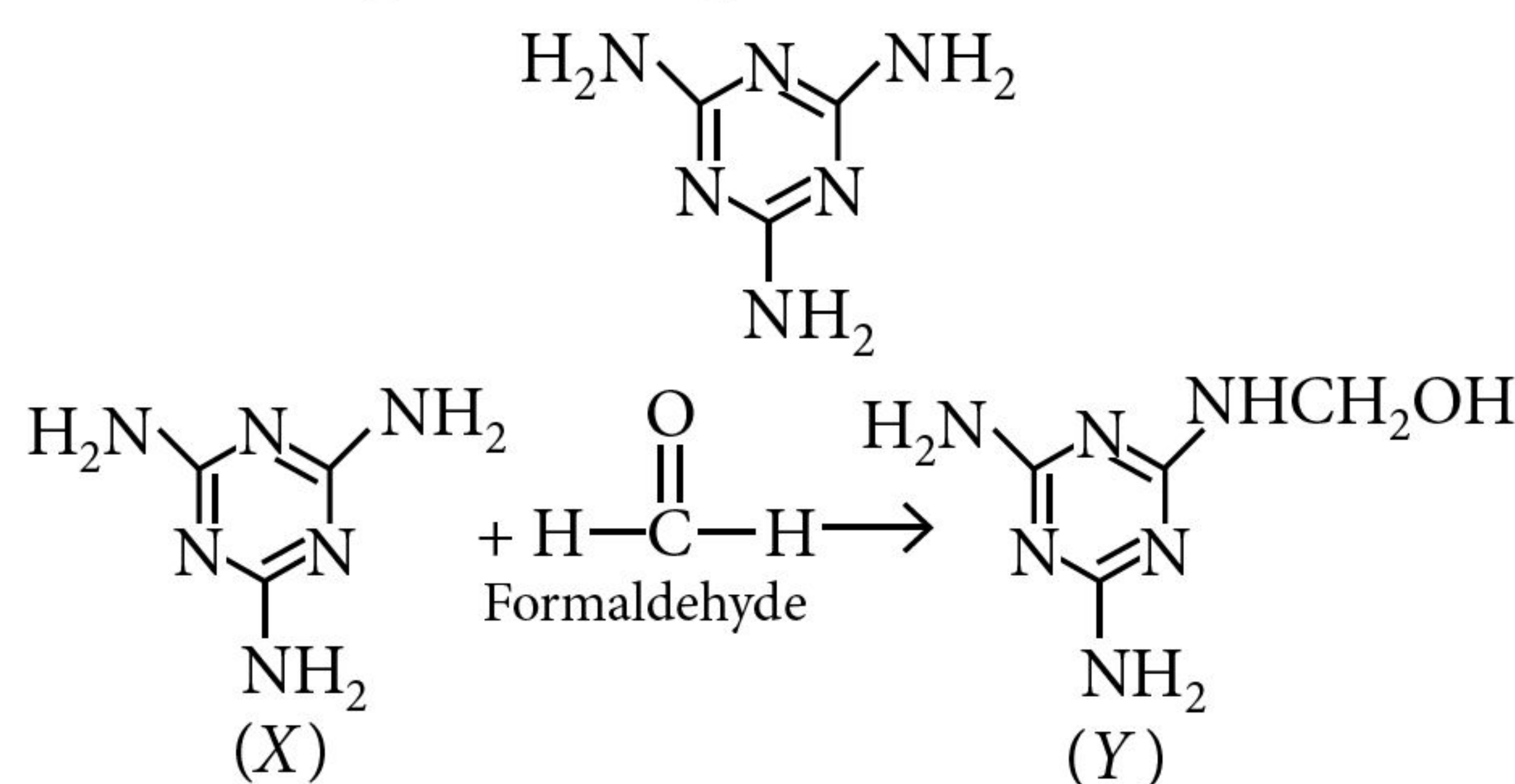
21. (2)

22. (1) : Sulphur exists in S_2 form in vapour phase which has two unpaired electrons while α -sulphur and β -sulphur are diamagnetic.

23. (5) : N_2O_5 ;



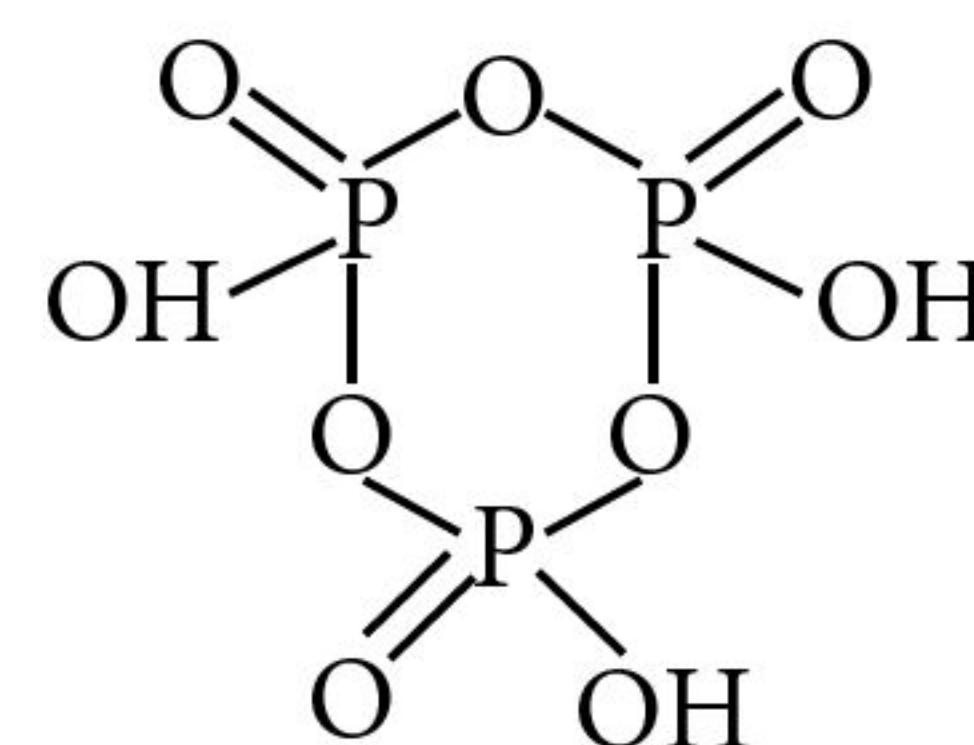
24. (4) : Monomers for melamine polymer are melamine and formaldehyde. Thus, X is melamine. No. of carbon atoms, $p = 3$
No. of nitrogen atoms, $q = 6$



No. of double bonds in X and Y are 3 each. So, total no. of double bonds, $r = 3 + 3 = 6$

Thus, $\frac{q+r}{p} = \frac{6+6}{3} = 4$

25. (3) : The structure of cyclotrimetaphosphoric acid is as follows :



In this structure, three P — O — P bonds are present

Class XII

Monthly test



This specially designed column enables students to self analyse their extent of understanding of all chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

Solutions | Metallurgy

Total Marks : 120

Time taken : 60 Min.

NEET

Only One Option Correct Type

- Henry's law constants for aqueous solution of CO, O₂, CO₂ and C₂H₂ gases at 25°C are respectively as 58×10^3 , 43×10^3 , 1.61×10^3 and 1.34×10^3 . The solubility of these gases decreases in the order
 - CO > O₂ > CO₂ > C₂H₂
 - O₂ > CO₂ > CO > C₂H₂
 - C₂H₂ > CO₂ > O₂ > CO
 - O₂ > CO₂ > C₂H₂ > CO
- In water saturated air, the mole fraction of water vapour is 0.02. If the total pressure of the saturated air is 1.2 atm, the partial pressure of dry air is
 - 1.18 atm
 - 1.76 atm
 - 1.176 atm
 - 0.98 atm.
- Which of the following is dependent on temperature?
 - Molarity
 - Mole fraction
 - Weight percentage
 - Molality
- The mixture that forms maximum boiling azeotrope is
 - heptane + octane
 - water + nitric acid
 - ethanol + water
 - acetone + carbon disulphide.
- The correct equation for the degree of association ' α ' of an associating solute, ' n ' molecules of which undergoes association in solution, is
 - $\alpha = \frac{n(i-1)}{1-n}$
 - $\alpha = \frac{i(n-1)}{1+n}$
 - $\alpha = \frac{i(n+1)}{1-n}$
 - $\alpha = \frac{i(n+1)}{n-1}$
- The boiling point of 0.2 mol kg⁻¹ solution of X in water is greater than equimolal solution of Y in water. Which one of the following statements is true in this case?
 - Molecular mass of X is less than the molecular mass of Y.
 - Y is undergoing dissociation in water while X undergoes no change.
 - X is undergoing dissociation in water.
 - Molecular mass of X is greater than the molecular mass of Y.
- Which of the following statements is correct regarding a solution of two components A and B exhibiting positive deviation from ideal behaviour?
 - Intermolecular attractive forces between A-A and B-B are stronger than those between A-B.
 - $\Delta_{\text{mix}}H = 0$ at constant T and P .
 - $\Delta_{\text{mix}}V = 0$ at constant T and P .
 - Intermolecular attractive forces between A-A and B-B are equal to those between A-B.
- Least freezing point amongst the following is
 - K₂SO₄
 - NaCl
 - urea
 - glucose.
- The solubility of a solid in a liquid is significantly affected by temperature changes.
 Solute + Solvent $\rightleftharpoons$ Solution
 The system being in a dynamic equilibrium must follow Le-chatelier's principle. Considering the Le-chatelier's principle which of the following is correct?

- (a) $\Delta H_{\text{sol}} > 0$; solubility $\uparrow$; temperature $\downarrow$
 (b) $\Delta H_{\text{sol}} < 0$; solubility $\downarrow$; temperature $\uparrow$
 (c) $\Delta H_{\text{sol}} > 0$; solubility $\downarrow$; temperature $\uparrow$
 (d) $\Delta H_{\text{sol}} < 0$; solubility $\uparrow$; temperature $\uparrow$

10. What will be the percentage of dimerization of 61 g of benzoic acid in 1000 g of a solvent and producing a depression in freezing point of 2 °C? Consider K_f to be 6.

- (a) 72% (b) 67%
 (c) 43% (d) 28%

11. 1.8 g of fructose ($\text{C}_6\text{H}_{12}\text{O}_6$) is added to 2 kg of water. The freezing point of solution is ($K_f = 1.86 \text{ K kg mol}^{-1}$)

- (a) -0.0093°C (b) 0.0093°C
 (c) -0.0186°C (d) -1.86°C

12. Which of the following sets of solutions of urea (mol. mass 60 g mol^{-1}) and sucrose (mol. mass 342 g mol^{-1}) is isotonic?

- (a) 9.1 g L^{-1} urea and 6.0 g L^{-1} sucrose
 (b) 3.0 g L^{-1} urea and 3.0 g L^{-1} sucrose
 (c) 6.0 g L^{-1} urea and 9.0 g L^{-1} sucrose
 (d) 3.0 g L^{-1} urea and 17.1 g L^{-1} sucrose

Assertion & Reason Type

Directions : In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

- (a) If both assertion and reason are true and reason is the correct explanation of assertion.
 (b) If both assertion and reason are true but reason is not the correct explanation of assertion.
 (c) If assertion is true but reason is false.
 (d) If both assertion and reason are false.

13. **Assertion :** Vapour pressure of solvent A increases when a more volatile solvent B is added.

Reason : B is more volatile therefore vapour pressure of A is greater than that of B.

14. **Assertion :** Acetone and aniline shows negative deviations from Raoult's law.

Reason : H-bonding between acetone and aniline is stronger than that between acetone-acetone and aniline-aniline.

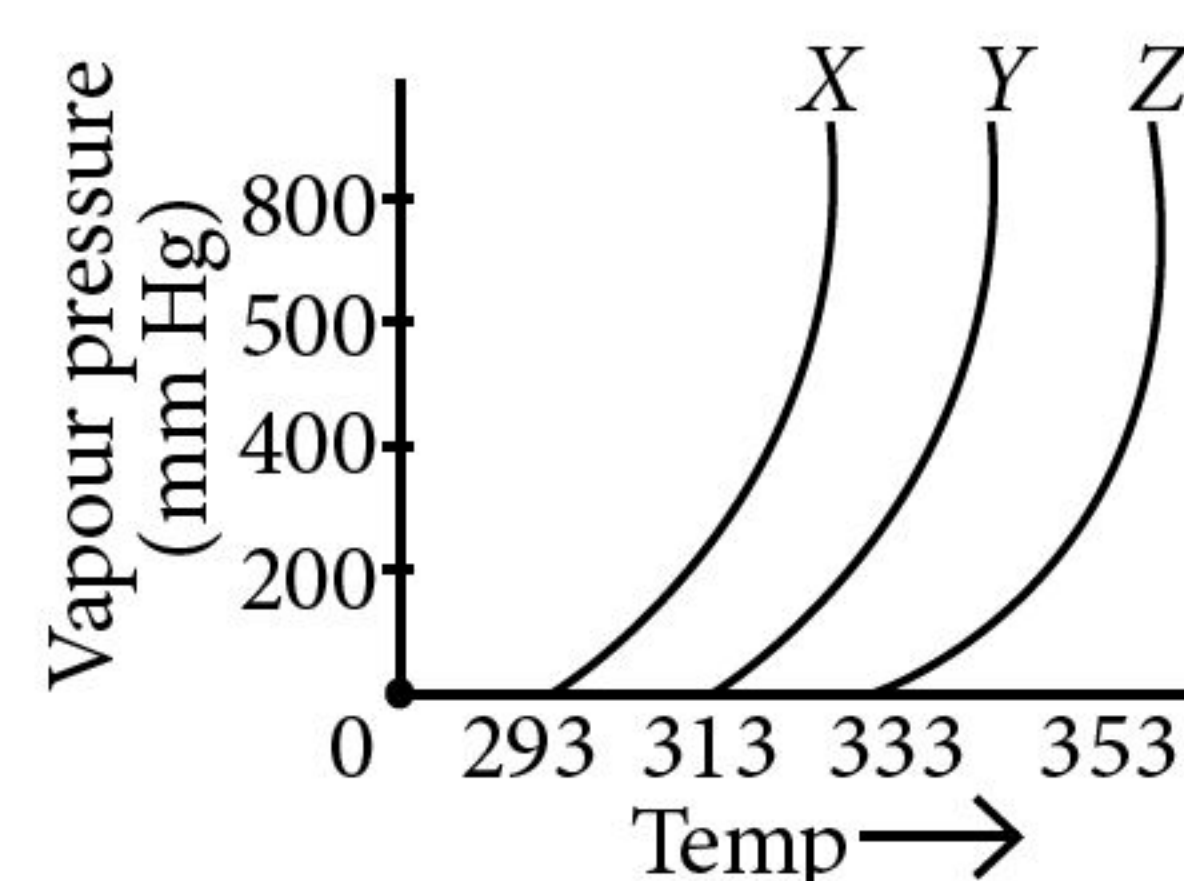
15. **Assertion :** Reverse osmosis is used in the desalination of sea water for getting drinking water.

Reason : When pressure more than osmotic pressure is applied, pure water is squeezed out of the sea water through the membrane.

JEE (Main & Advanced)

Only One Option Correct Type

16. A graph of vapour pressure and temperature for three different liquids X, Y and Z is shown below :



The following inferences are made

- (A) X has higher intermolecular interactions compared to Y.
 (B) X has lower intermolecular interactions compared to Y.
 (C) Z has lower intermolecular interactions compared to Y.

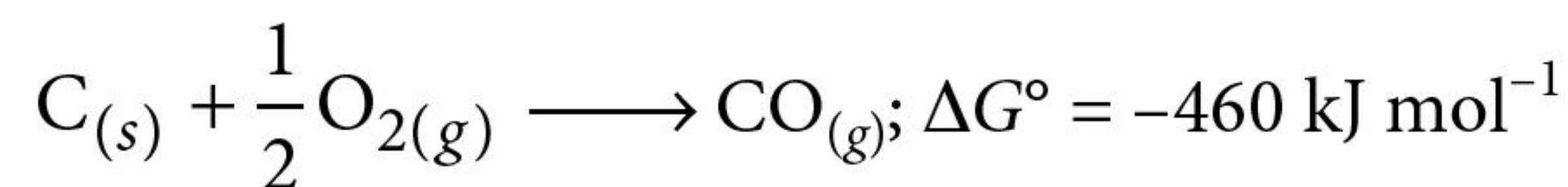
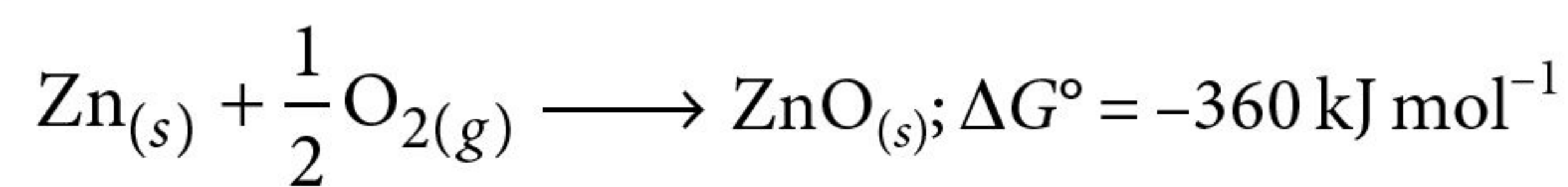
The correct inference(s) is/are

- (a) (C) (b) (A)
 (c) (B) (d) (A) and (C)

17. Two 5 molal solutions are prepared by dissolving a non-electrolyte, non-volatile solute separately in the solvents X and Y. The molecular weights of the solvents are M_X and M_Y , respectively where, $M_X = \frac{3}{4} M_Y$. The relative lowering of vapour pressure of the solution in X is "m" times that of the solution in Y. Given that the number of moles of solute is very small in comparison to that of solvent, the value of "m" is

- (a) $\frac{3}{4}$ (b) $\frac{4}{3}$ (c) $\frac{1}{2}$ (d) $\frac{1}{4}$

18. At 1000°C ,



Quotable Quote

“We cannot solve problems with the same thinking we used to create them.”

Albert Einstein

The correct statement is

- (a) zinc can be oxidised by carbon monoxide
- (b) zinc blend is produced during the reaction
- (c) zinc oxide can be reduced by graphite
- (d) zinc can be oxidised by graphite

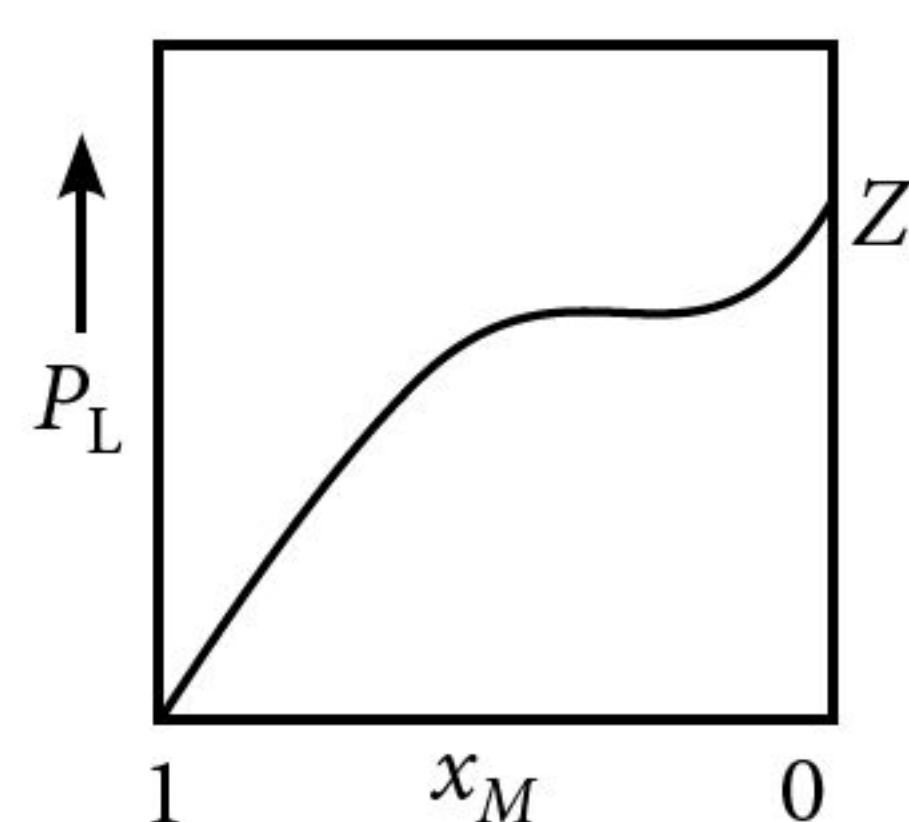
19. Complexes formed in the following methods are

- I. Mond's process for purification of nickel
- II. Removal of lead poisoning from the body
- III. Cyanide process for extraction of silver
- IV. Froth floatation process for separation of ZnS from galena ore by using depressant

- | | | | |
|-----------------------|--------------------------|--------------------------|--------------------------|
| I | II | III | IV |
| (a) Ni(CO)_4 | $[\text{Pb(EDTA)}]^{2-}$ | $[\text{Ag(CN)}_2]^-$ | $[\text{Zn(CN)}_2]$ |
| (b) Ni(CO)_4 | $[\text{Pb(EDTA)}]^{2-}$ | $[\text{Ag(CN)}_2]^-$ | $[\text{Zn(CN)}_4]^{2-}$ |
| (c) Ni(CO)_6 | $[\text{Pb(EDTA)}]^{4-}$ | $[\text{Ag(CN)}_2]^-$ | $[\text{Zn(CN)}_6]^{4-}$ |
| (d) Ni(CO)_4 | $[\text{Pb(EDTA)}]^{2-}$ | $[\text{Ag(CN)}_4]^{3-}$ | $[\text{Zn(CN)}_4]^{2-}$ |

More than One Option Correct Type

20. For a solution formed by mixing liquids L and M , the vapour pressure of L plotted against the mole fraction of M in solution is shown in the following figure. Here x_L and x_M represent mole fractions of L and M , respectively, in the solution. The correct statement(s) applicable to this system is(are)



- (a) attractive intermolecular interactions between L - L in pure liquid L and M - M in pure liquid M are stronger than those between L - M when mixed in solution
- (b) the point Z represents vapour pressure of pure liquid M and Raoult's law is obeyed when $x_L \rightarrow 0$
- (c) the point Z represents vapour pressure of pure liquid M and Raoult's law is obeyed from $x_L = 0$ to $x_L = 1$
- (d) the point Z represents vapour pressure of pure liquid L and Raoult's law is obeyed when $x_L \rightarrow 1$.

21. Henry's constant (in kbar) for four gases α , β , γ and δ in water at 298 K is given below :

Gas	α	β	γ	δ
K_H	50	2	2×10^{-5}	0.5

(density of water = 10^3 kg m^{-3} at 298 K)

This table implies that

- (a) α has the highest solubility in water at a given pressure
- (b) solubility of γ at 308 K is lower than at 298 K
- (c) the pressure of a 55.5 molal solution of γ is 1 bar
- (d) the pressure of a 55.5 molal solution of δ is 250 bar.

22. Froth floatation process used for the concentration of sulphide ore

- (a) is based on the difference in wettability of different minerals
- (b) uses sodium ethyl xanthate, $\text{C}_2\text{H}_5\text{OCS}_2\text{Na}$, as collector
- (c) uses NaCN as depressant in the mixture of ZnS and PbS when ZnS forms soluble complex and PbS forms froth
- (d) uses aniline as froth stabilisers.

23. For which reaction(s) $\Delta_f G^\circ$ vs T plot in Ellingham diagram slopes upward?

- (a) $\text{Mg} + \frac{1}{2} \text{O}_2 \longrightarrow \text{MgO}$
- (b) $2\text{Ag} + \frac{1}{2} \text{O}_2 \longrightarrow \text{Ag}_2\text{O}$
- (c) $\text{C} + \frac{1}{2} \text{O}_2 \longrightarrow \text{CO}$
- (d) $\text{CO} + \frac{1}{2} \text{O}_2 \longrightarrow \text{CO}_2$

Integer / Numerical Value Type

24. The elevation of boiling point of 0.10 m aqueous $\text{CrCl}_3 \cdot x\text{NH}_3$ solution is two times that of 0.05 m aqueous CaCl_2 solution. The value of x is _____. [Assume 100% ionisation of the complex and CaCl_2 , coordination number of Cr as 6, and that all NH_3 molecules are present inside the coordination sphere]

25. AB_2 is 10% dissociated in water to A^{2+} and B^- . The boiling point of a 10.0 molal aqueous solution of AB_2 is _____ °C. (Round off to the Nearest Integer)

[Given : Molal elevation constant of water, $K_b = 0.5 \text{ K kg mol}^{-1}$; boiling point of pure water = 100°C]

26. Among the given metals, the total number of metals that can be purified by using zone refining method is _____.

Cu, Sn, Si, Al, Au, Ga, Ti, B, Ge, Zn, Zr, In, Ni, Hg

Comprehension Type

The electrolyte solutions show abnormal colligative properties. To account for this effect we define a quantity called the van't Hoff factor given by

$$i = \frac{\text{Actual number of particles in solution after dissociation}}{\text{Number of formula units initially dissolved in solution}}$$

$i = 1$ (for non-electrolytes)

$i > 1$ (for electrolytes, undergoing dissociation)

$i < 1$ (for solutes undergoing association)

27. Benzoic acid undergoes dimerisation in benzene solution. The van't Hoff factor (i) is related to the degree of association (α) of the acid as

(a) $i = 2 - \alpha$

(b) $i = 1 + (\alpha/3)$

(c) $i = 1 - (\alpha/2)$

(d) $i = 1 + (\alpha/2)$

28. Van't Hoff factors of equimolar solutions of sodium chloride, barium chloride and glucose in water are

(a) 2, 3, 0 respectively

(b) 2, 3, 6 respectively

(c) 2, 3, 4 respectively

(d) 2, 3, 1 respectively.

Matching Type

29. Match the column I with column II and mark the appropriate choice.

Column I (Electrolytes)		Column II (van't Hoff factor i)	
A.	Hg_2Cl_2 (Complete ionisation)	P.	4
B.	C_6H_5COOH in benzene	Q.	3
C.	C_6H_5COOH in H_2O	R.	less than 1
D.	$K_3[Fe(CN)_6]$ (Complete ionisation)	S.	1

(a) $A \rightarrow P, B \rightarrow Q, C \rightarrow R, D \rightarrow S$

(b) $A \rightarrow S, B \rightarrow P, C \rightarrow Q, D \rightarrow R$

(c) $A \rightarrow R, B \rightarrow S, C \rightarrow P, D \rightarrow Q$

(d) $A \rightarrow Q, B \rightarrow R, C \rightarrow S, D \rightarrow P$

30. Match the column I with column II and select the correct option.

Column I		Column II	
(A)	Sphalerite	(i)	$FeCO_3$
(B)	Malachite	(ii)	$ZnCO_3$
(C)	Calamine	(iii)	Na_3AlF_6
(D)	Cryolite	(iv)	$CuCO_3 \cdot Cu(OH)_2$
(E)	Siderite	(v)	ZnS

(a) (A) - (iii), (B) - (i), (C) - (v), (D) - (ii), (E) - (iv)

(b) (A) - (v), (B) - (iv), (C) - (ii), (D) - (i), (E) - (iii)

(c) (A) - (v), (B) - (iii), (C) - (ii), (D) - (i), (E) - (iv)

(d) (A) - (v), (B) - (iv), (C) - (ii), (D) - (iii), (E) - (i)



UNSCRAMBLED WORDS

JUNE 2025

1-(d) EFFUSION

6-(j) BITUMEN

2-(f) LIGAND

7-(h) BERKELIUM

3-(b) DELOCALIZATION

8-(c) ELECTROLYTE

4-(i) CHELATE

9-(g) ALKALINE

5-(a) CALORIMETRY

10-(e) KETONE

Winners : Ankita, Neha

Keys are published in this issue. Search now! ☺

SELF CHECK

No. of questions attempted

No. of questions correct

Marks scored in percentage

Check your score! If your score is

> 90% EXCELLENT WORK !

You are well prepared to take the challenge of final exam.

90-75% GOOD WORK !

You can score good in the final exam.

74-60% SATISFACTORY !

You need to score more next time.

< 60% NOT SATISFACTORY!

Revise thoroughly and strengthen your concepts.



CLASS-XII

CBSE

Warm-up!

Chapterwise practice questions for CBSE Exams as per the latest pattern and syllabus by CBSE for the academic session 2025-26.

Series-2

Electrochemistry

General Instructions : Read the following instructions carefully and follow them :

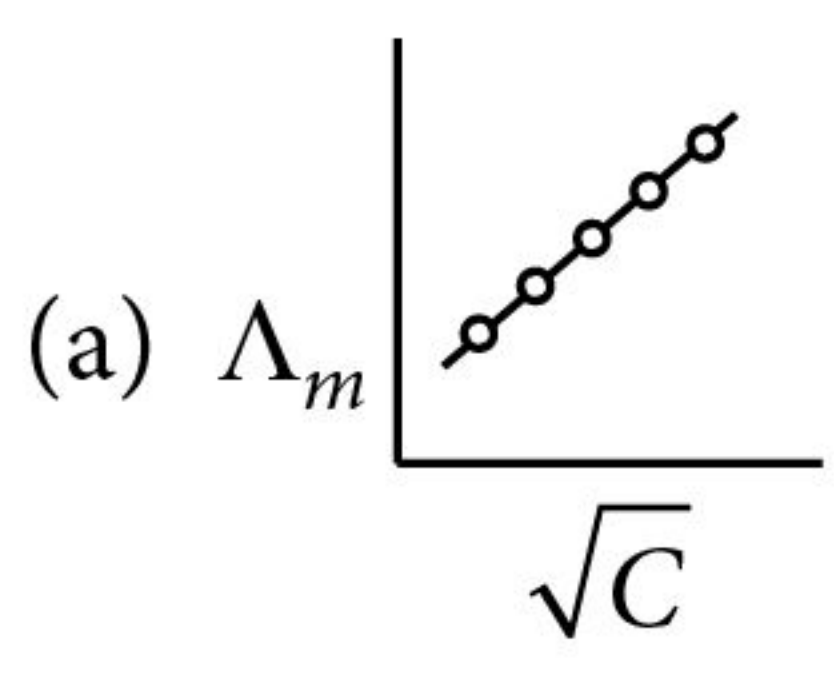
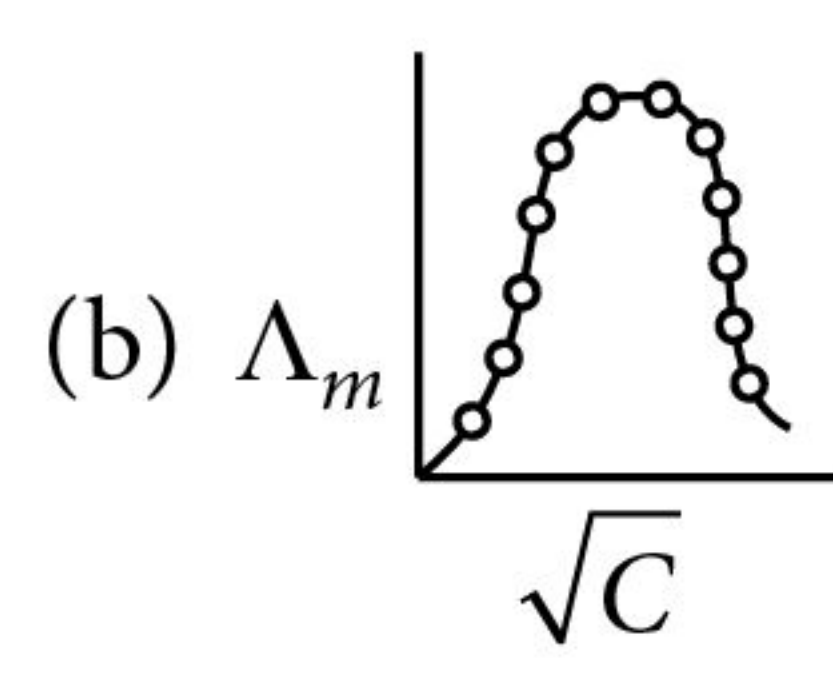
- (i) This question paper contains 33 questions. All questions are compulsory.
- (ii) Question paper is divided into five sections – Section A, B, C, D and E.
- (iii) Section A – questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.
- (iv) Section B – questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.
- (v) Section C – questions number 22 to 28 are short answer type questions. Each question carries 3 marks.
- (vi) Section D – questions number 29 to 30 are case-based questions. Each question carries 4 marks.
- (vii) Section E – questions number 31 to 33 are long answer type questions. Each question carries 5 marks.
- (viii) There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the sections except section A.
- (ix) Kindly note that there is a separate question paper for Visually Impaired candidates.
- (x) Use of calculators is not allowed.

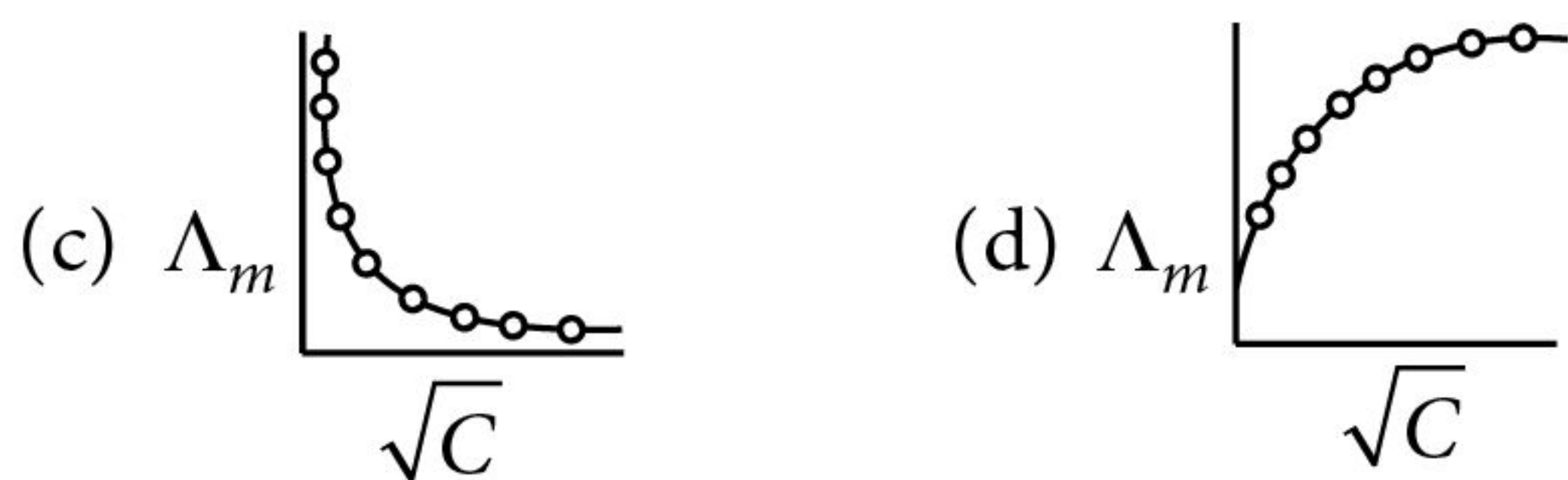
Time Allowed : 3 hours

Maximum Marks : 70

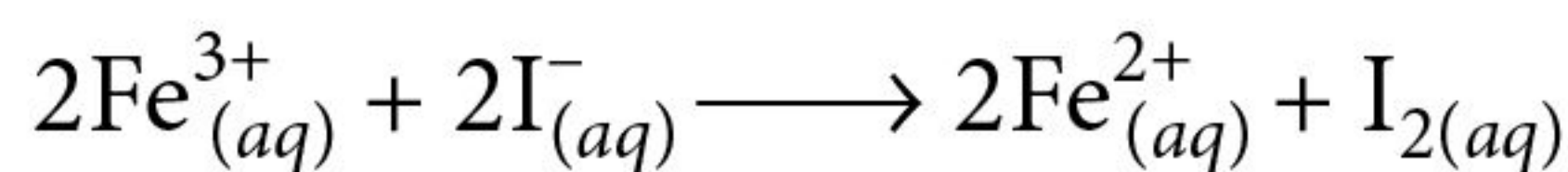
SECTION-A

Question No. 1 to 16 are multiple choice type questions carrying 1 mark each.

1. When $[\text{Zn}^{2+}] = [\text{Cu}^{2+}] = 1$, the electrical potential of Daniell cell is 1.1 V. However,
 - (a) when $E_{\text{ext}} < 1.1$ V, current flows from Zn to Cu
 - (b) when $E_{\text{ext}} = 1.1$ V, current flows from Cu to Zn
 - (c) when $E_{\text{ext}} > 1.1$ V, current flows from Zn to Cu
 - (d) when $E_{\text{ext}} < 1.1$ V, electrons flow from Cu to Zn.
2. $\text{Zn} \longrightarrow \text{Zn}^{2+} + 2e^-$; $E^\circ = +0.76$ V
 $\text{Fe} \longrightarrow \text{Fe}^{2+} + 2e^-$; $E^\circ = +0.41$ V
The e.m.f. for the cell reaction $\text{Fe}^{2+} + \text{Zn} \longrightarrow \text{Zn}^{2+} + \text{Fe}$ is
 - (a) -0.35 V (b) $+0.35$ V
 - (c) $+1.17$ V (d) -1.17 V
3. The potential of a H_2 electrode which is dipped in a solution of $\text{pH} = 10$ is
 - (a) zero (b) 1 V (c) 2 V (d) 0.592 V
4. An electrochemical cell has two half-cell reactions as
 $\text{A}^{2+} + 2e^- \longrightarrow \text{A}$; $E^\circ_{\text{A}^{2+}/\text{A}} = 0.34$ V
 $\text{X} \longrightarrow \text{X}^{2+} + 2e^-$; $E^\circ_{\text{X}^{2+}/\text{X}} = -2.37$ V
The cell voltage will be
 - (a) 2.71 V (b) 2.03 V (c) -2.71 V (d) -2.03 V
5. Saturated solution of KNO_3 is used to make 'salt bridge' because
 - (a) velocity of K^+ is greater than that of NO_3^-
 - (b) velocity of NO_3^- is greater than that of K^+
 - (c) velocities of both K^+ and NO_3^- are nearly the same
 - (d) KNO_3 is highly soluble in water.
6. The variation of Λ_m of acetic acid with concentration is correctly represented by
 - (a) 
 - (b) 



7. For the cell reaction :



$E_{\text{cell}}^{\circ} = 0.24 \text{ V}$ at 298 K. The standard Gibbs energy ($\Delta_r G^{\circ}$) of the cell reaction is

[Given that Faraday constant, $F = 96500 \text{ C mol}^{-1}$]

- (a) $23.16 \text{ kJ mol}^{-1}$ (b) $-46.32 \text{ kJ mol}^{-1}$
(c) $-23.16 \text{ kJ mol}^{-1}$ (d) $46.32 \text{ kJ mol}^{-1}$

8. The equilibrium constant (K_c) for the reaction $\text{Cu}_{(s)} + 2\text{Ag}_{(aq)}^{+} \longrightarrow \text{Cu}_{(aq)}^{2+} + 2\text{Ag}_{(s)}$ will be

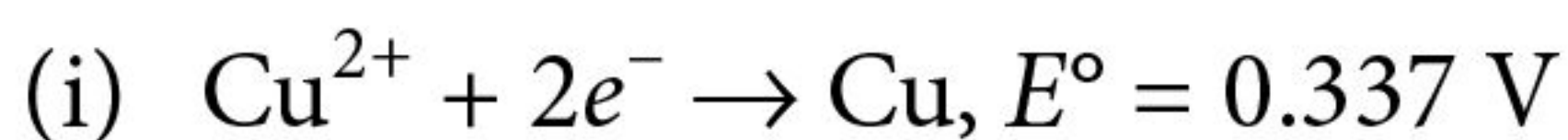
[Given $E_{\text{cell}}^{\circ} = 0.46$]

- (a) $K_c = \text{Antilog } 15.6$ (b) $K_c = \text{Antilog } 2.5$
(c) $K_c = \text{Antilog } 1.5$ (d) $K_c = \text{Antilog } 12.2$

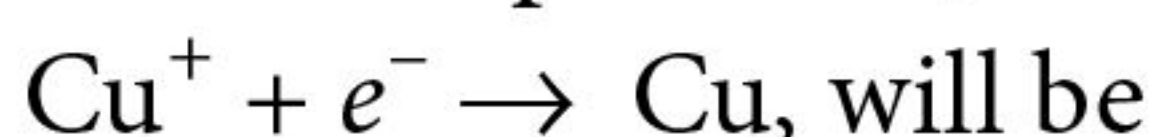
9. How many Faradays are required to reduce 1 mol of $\text{Cr}_2\text{O}_7^{2-}$ to Cr^{3+} in acidic medium?

- (a) 2 (b) 3 (c) 5 (d) 6

10. Given :



Electrode potential, E° for the reaction,



- (a) 0.90 V (b) 0.30 V
(c) 0.38 V (d) 0.52 V

11. E_1 , E_2 and E_3 are the emf values of the three galvanic cells respectively.



Which one of the following is true?

- (a) $E_2 > E_3 > E_1$ (b) $E_3 > E_2 > E_1$
(c) $E_1 > E_2 > E_3$ (d) $E_1 > E_3 > E_2$

12. What is the amount of chlorine evolved when 2 ampere of current is passed for 30 minutes in an aqueous solution of NaCl?

- (a) 66 g (b) 1.32 g (c) 33 g (d) 99 g

For questions number 13 to 16, two statements are given- one labelled as Assertion (A) and the other labelled as Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below:

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false, but Reason (R) is true.

13. **Assertion (A)** : Molar conductivity of a weak electrolyte at infinite dilution cannot be determined experimentally.

Reason (R) : Kohlrausch law helps to find the molar conductivity of a weak electrolyte at infinite dilution.

14. **Assertion (A)** : Conductivity of all electrolytes decreases on dilution.

Reason (R) : On dilution number of ions per unit volume decreases.

15. **Assertion (A)** : To obtain maximum work from a galvanic cell charge has to be passed reversibly.

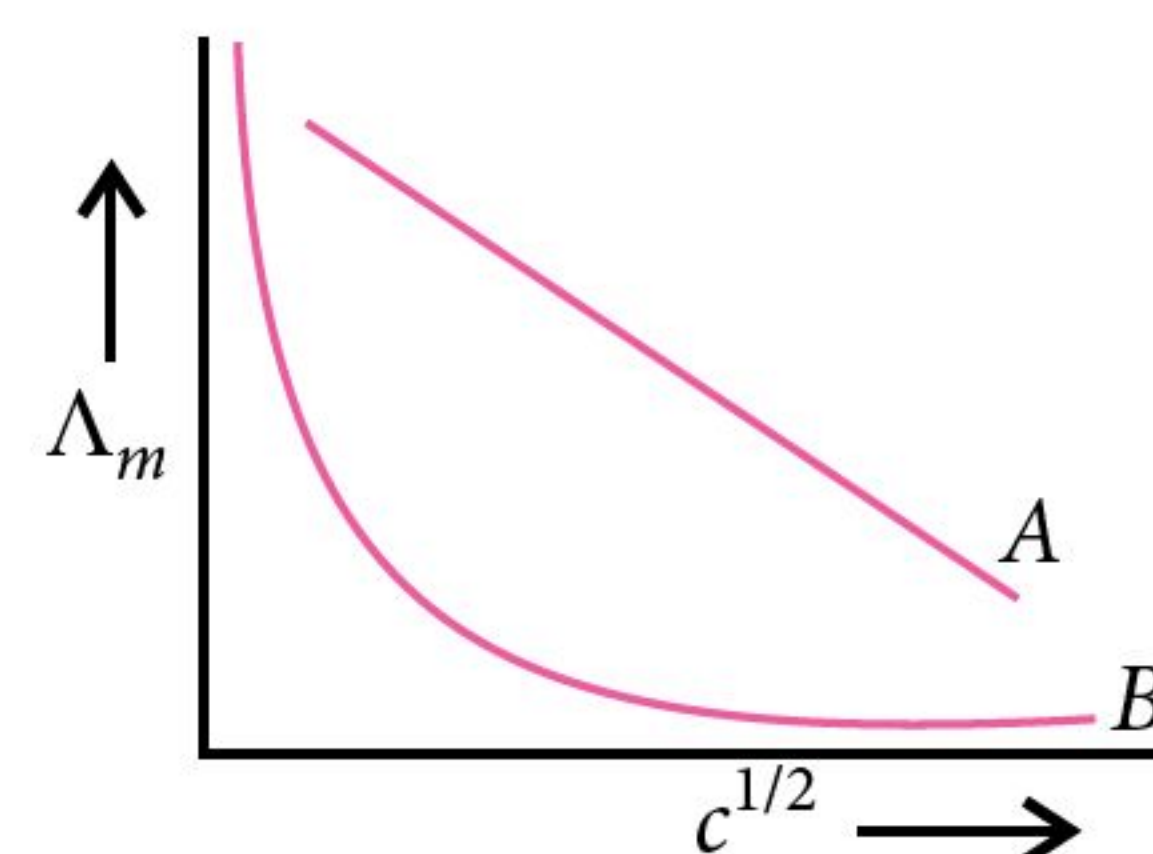
Reason (R) : The reversible work done by a galvanic cell is equal to decrease in its Gibbs energy.

16. **Assertion (A)** : 96500 C charge is required for the reduction of one mole of silver ions.

Reason (R) : The amount of electricity (or charge) required for oxidation or reduction depends on the stoichiometry of the electrode reaction.

SECTION-B

17. In the plot of molar conductivity (Λ_m) vs square root of concentration ($c^{1/2}$), following curves are obtained for two electrolytes A and B



Answer the following :

(i) Predict the nature of electrolytes A and B.

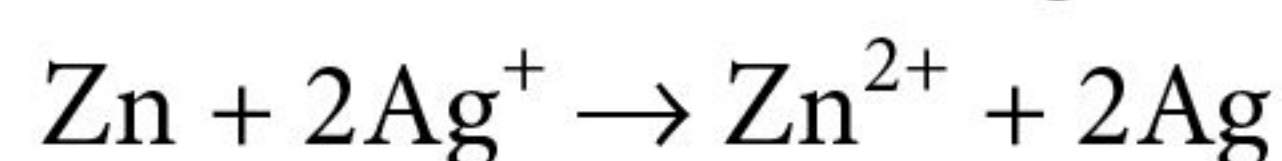
(ii) What happens on extrapolation of Λ_m to concentration approaching zero for electrolyte A?

18. (A) (a) On electrolysis of an aqueous solution of NaCl, why H_2 and not Na is liberated at the cathode?

- (b) One faraday of electricity deposits one mole of Na from the molten salt but $\frac{1}{3}$ mol of Al from an aluminium salt. Why?

OR

- (B) (a) Calculate the standard EMF of a cell which involves the following cell reaction,



Given, $E^\circ_{\text{Zn}|\text{Zn}^{2+}} = 0.76 \text{ V}$ and $E^\circ_{\text{Ag}|\text{Ag}^+} = -0.80 \text{ V}$

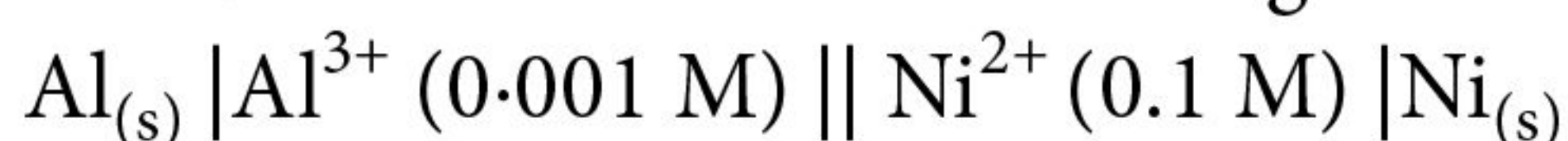
- (b) For the following cell



$E^\circ_{\text{Fe}^{3+}/\text{Fe}^{2+}} = 0.771 \text{ V}$ and $E^\circ_{\text{Sn}^{4+}/\text{Sn}^{2+}} = 0.15 \text{ V}$

Is the cell reaction spontaneous?

19. Calculate the emf of the following cell at 25°C :



Given : $E^\circ_{(\text{Ni}^{2+}/\text{Ni})} = -0.25 \text{ V}$

$E^\circ_{(\text{Al}^{3+}/\text{Al})} = -1.66 \text{ V}$

$[\log 2 = 0.3010, \log 3 = 0.4771]$

20. From the given cells :

Lead storage cell, Mercury cell, Fuel cell and Dry cell

Answer the following :

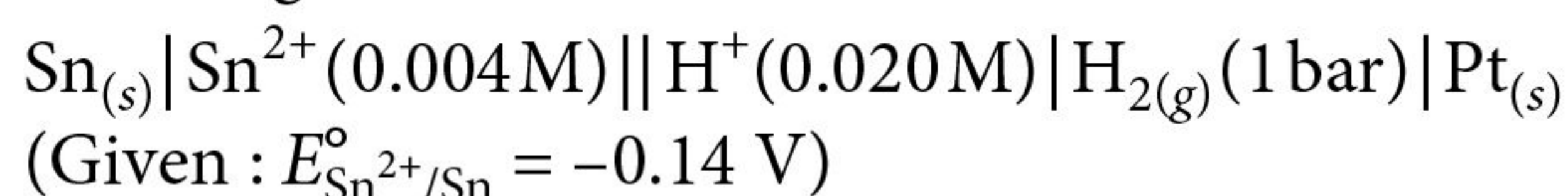
- Which cell is used in hearing aids?
 - Which cell was used in Apollo space programme?
 - Which cell is used in automobiles and inverters?
 - Which cell does not have long life?
21. Calculate the molar conductivity of NH_4OH at infinite dilution if molar conductivities at infinite dilution for $\text{Ba}(\text{OH})_2$, BaCl_2 and NH_4Cl are 523.28, 280.0 and $129.8 \text{ S cm}^2 \text{ mol}^{-1}$ respectively.
22. X and Y are two electrolytes. On dilution molar conductivity of 'X' increases 2.5 times while that Y increases 25 times. Which of the two is a weak electrolyte and why?

SECTION-C

23. How many molecules of chlorine should be deposited from molten sodium chloride in one minute by a current of 300 milliampere?
24. Calculate $\Delta_r G^\circ$ and $\log K_c$ for the following reaction.
- $$\text{Cd}_{(aq)}^{2+} + \text{Zn}_{(s)} \longrightarrow \text{Zn}_{(aq)}^{2+} + \text{Cd}_{(s)}$$
- Given : $E^\circ_{\text{Cd}^{2+}/\text{Cd}} = -0.403 \text{ V}$; $E^\circ_{\text{Zn}^{2+}/\text{Zn}} = -0.763 \text{ V}$

OR

Write the cell reaction and calculate the e.m.f. of the following cell at 298 K.



25. 0.04 M solution of a weak monobasic acid has a conductivity $4.23 \times 10^{-4} \text{ S cm}^{-1}$ and limiting molar conductivity $172.8 \text{ S cm}^2 \text{ mol}^{-1}$. Calculate the degree of dissociation.
26. At what pH of HCl solution will hydrogen gas electrode show electrode potential of -0.118 V ? H_2 gas is bubbled at 298 K and 1 atm pressure.
27. Chromium metal is electroplated using an acidic solution containing CrO_3 according to the following equation :
- $$\text{CrO}_{3(aq)} + 6\text{H}^+ + 6e^- \rightarrow \text{Cr}_{(s)} + 3\text{H}_2\text{O}$$
- Calculate how many grams of chromium will be electroplated by 24,000 coulombs. How long will it take to electroplate 1.5 g chromium using 12.5 A current?
- [Atomic mass of Cr = 52 g mol^{-1} ,
1 F = 96500 C mol^{-1}]
28. For the reaction,
- $$2\text{AgCl}_{(s)} + \text{H}_{2(g)}(1 \text{ atm}) \rightarrow 2\text{Ag}_{(s)} + 2\text{H}^+(0.1 \text{ M}) + 2\text{Cl}^-(0.1 \text{ M})$$
- $\Delta G^\circ = -43600 \text{ J}$ at 25°C .
Calculate the e.m.f. of the cell.

SECTION-D

The following questions are case-based questions. Read the passage carefully and answer the questions that follow.

29. For an electrode reaction written as,
- $$\text{M}^{n+} + ne^- \rightarrow \text{M}$$

$$E_{\text{red}} = E^\circ_{\text{red}} - \frac{RT}{nF} \ln \frac{1}{[\text{M}^{n+}]} \quad (\text{Nernst equation})$$

$$= E^\circ_{\text{red}} - \frac{0.0591}{n} \log \frac{1}{[\text{M}^{n+}]} \quad \text{at } 298 \text{ K.}$$

For the cell reaction, $a\text{A} + b\text{B} \rightleftharpoons x\text{X} + y\text{Y}$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{nF} \log \frac{[\text{X}]^x [\text{Y}]^y}{[\text{A}]^a [\text{B}]^b}$$

$$= E^\circ_{\text{cell}} - \frac{0.0591}{n} \log \frac{[\text{X}]^x [\text{Y}]^y}{[\text{A}]^a [\text{B}]^b} \quad \text{at } 298 \text{ K}$$

For pure solids, liquids or gases at 1 atm, molar concentration = 1.

Standard free energy change, $\Delta G^\circ = -nFE^\circ_{\text{cell}}$ where n is the number of electrons transferred in the redox reaction of the cell, E°_{cell} is the standard emf of the cell. F stands for 1 faraday i.e. 96500 C mol^{-1} .

Standard free energy change,

$$\Delta G^\circ = -2.303RT \log K_C,$$

where K_C is the equilibrium constant at $T \text{ K}$. K_C can be calculated from E°_{cell} by using the relation

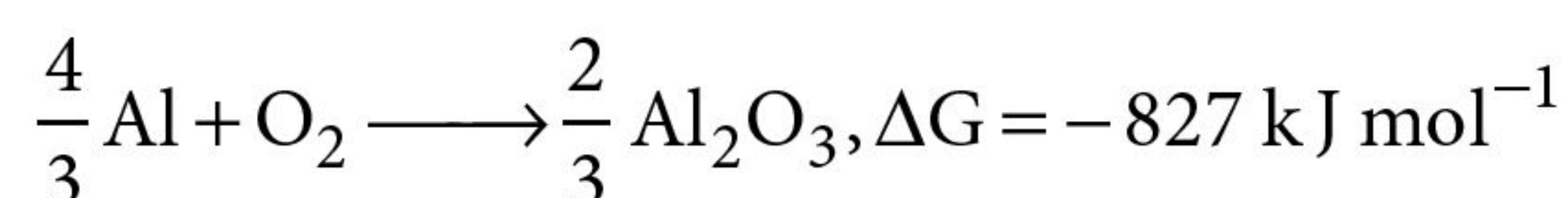
$$E^\circ_{\text{cell}} = \frac{0.0591}{n} \times \log K_C.$$

(a) The emf of the cell $\text{Zn}|\text{Zn}^{2+} (0.01\text{M})||\text{Fe}^{2+} (0.001 \text{ M})|\text{Fe}$ at 298 K is 0.2905 V . Calculate the value of equilibrium constant.

(b) E° for the cell, $\text{Zn}|\text{Zn}^{2+}_{(\text{aq})}||\text{Cu}^{2+}_{(\text{aq})}|\text{Cu}$ is 110 V at 25°C . What will be equilibrium constant for the cell reaction $\text{Zn} + \text{Cu}^{2+}_{(\text{aq})} \rightleftharpoons \text{Cu} + \text{Zn}^{2+}_{(\text{aq})}$

OR

(b) On the basis of information available from the reaction



What will be the minimum emf required to carry out an electrolysis of Al_2O_3

(c) The standard emf of a galvanic cell involving cell reaction with $n = 2$ is found to be 0.295 V at 25°C . Calculate the equilibrium constant.

30. The electrochemical cell shown below is concentration cell.

$M|M^{2+}$ (saturated solution of a sparingly soluble salt, MX_2) $|| M^{2+} (0.001 \text{ mol dm}^{-3})|M$

The emf of the cell depends on the difference in concentrations of M^{2+} ions at the two electrodes. The emf of the cell at 298 K is 0.059 V .

(a) Calculate the solubility product (K_{sp} in $\text{mol}^3 \text{ L}^{-3}$) of MX_2 at 298 K based on the information available for the given concentration cell.

(Take $2.303 \times R \times 298/F = 0.059$)

(b) The standard electrode potential (E°) for OCl^-/Cl^- and $\text{Cl}^-/\frac{1}{2}\text{Cl}_2$ respectively are 0.94 V and -1.36 V . What will be the E° value for $\text{OCl}^-/\frac{1}{2}\text{Cl}_2$?

(c) Calculate the value of ΔG (in kJ mol^{-1}) for the given cell. (Take $1 F = 96500 \text{ C mol}^{-1}$)

OR

(c) For the given cell, What will be the value of equilibrium constant.

SECTION-E

31. (A) (i) The resistance of a conductivity cell containing 0.001 M KCl solution at 298 K is 1500Ω . What is the cell constant if the conductivity of 0.001 M KCl solution at 298 K is $0.146 \times 10^{-3} \text{ S cm}^{-1}$?

(ii) Calculate the degree of dissociation of acetic acid at 298 K , given that :

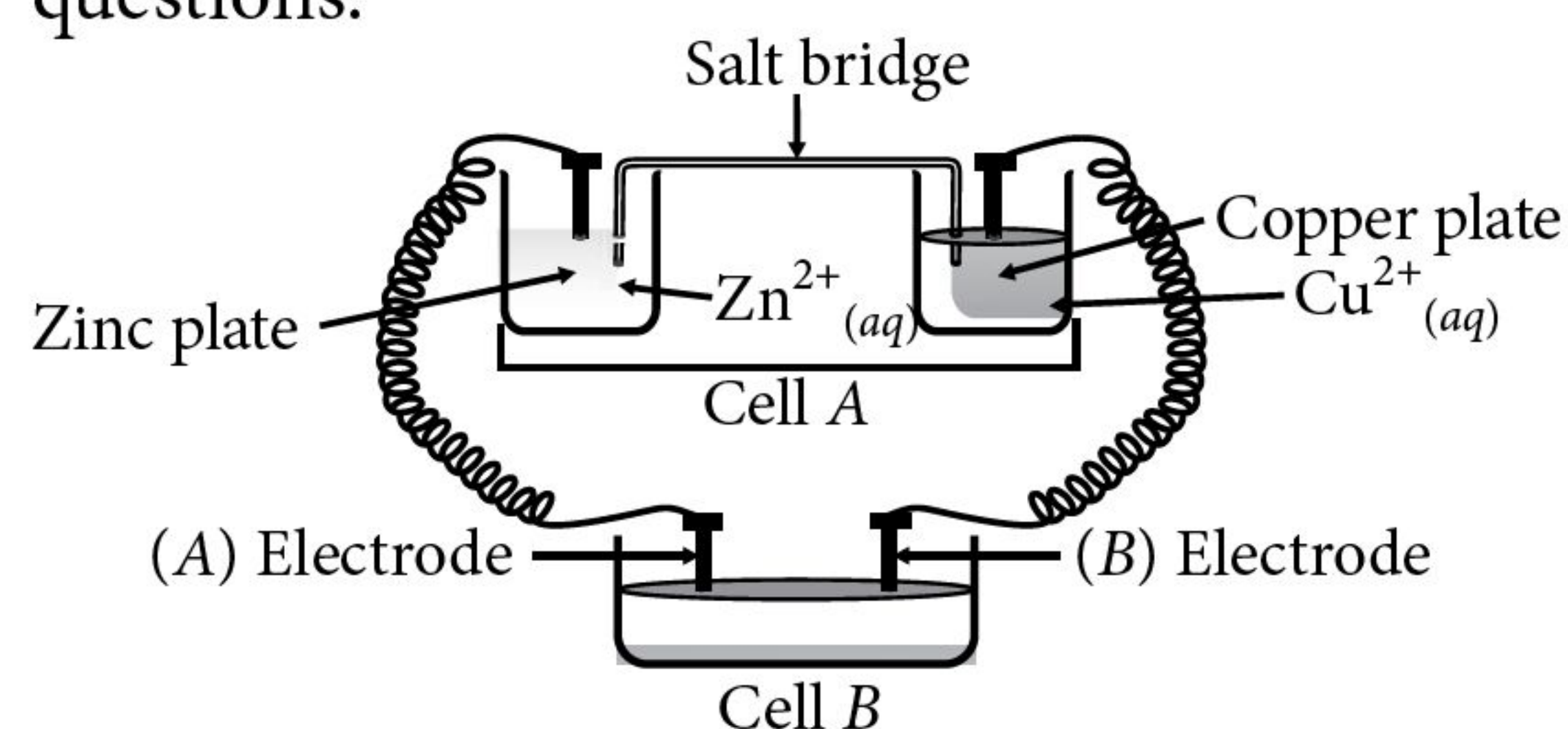
$$\Lambda_m(\text{CH}_3\text{COOH}) = 11.7 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\Lambda^\circ_m(\text{CH}_3\text{COO}^-) = 49.9 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\Lambda^\circ_m(\text{H}^+) = 349.1 \text{ S cm}^2 \text{ mol}^{-1}$$

OR

(B) Consider the figure and answer the following questions.

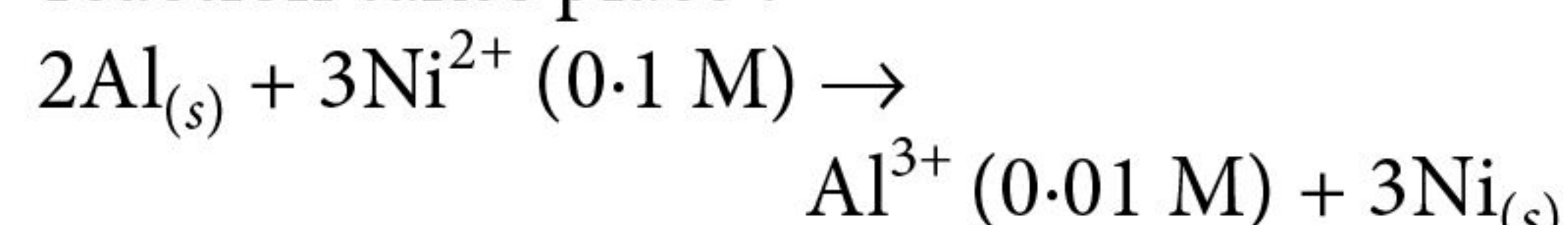


(i) Cell 'A' has $E_{\text{cell}} = 2 \text{ V}$ and cell 'B' has $E_{\text{cell}} = 1.1 \text{ V}$ which of the two cells 'A' or 'B' will act as an electrolytic cell? Which electrode reactions will occur in this cell?

(ii) If cell 'A' has $E_{\text{cell}} = 0.5 \text{ V}$ and cell 'B' has $E_{\text{cell}} = 1.1 \text{ V}$ then what will be the reactions at anode and cathode?

(iii) Calculate the potential for half-cell containing $0.10 \text{ M K}_2\text{Cr}_2\text{O}_7(\text{aq})$, $0.20 \text{ M Cr}^{3+}(\text{aq})$ and $1.0 \times 10^{-4} \text{ M H}^+(\text{aq})$. The half cell reaction is : $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6e^- \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$ and the standard electrode potential is given as $E^\circ = 1.33 \text{ V}$.

32. (A) (a) Represent the cell in which the following reaction takes place :

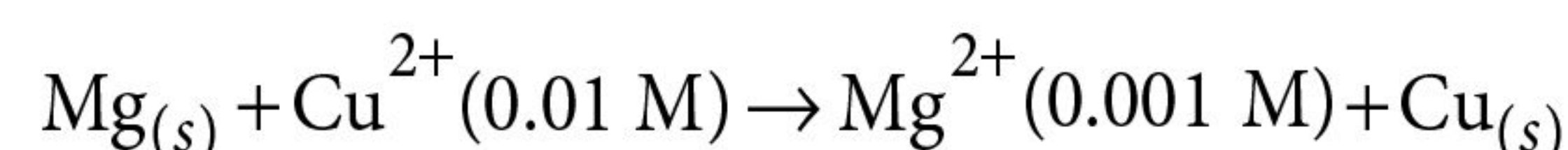


Calculate its emf if $E^\circ_{\text{cell}} = 1.41 \text{ V}$.

(b) Write the anode and cathode reactions and the overall cell reaction occurring in a lead storage battery during its use.

OR

(B) E°_{cell} for the given redox reaction is 2.71 V .



Calculate E_{cell} for the reaction. Write the direction of flow of current when an external opposite potential applied is

- (i) less than 2.71 V and
- (ii) greater than 2.71 V

33. (A) (i) A current of one ampere is flowing through a wire. Calculate the number of electrons flowing through the cross-section of the wire per second.
- (ii) Calculate the quantity of electricity that would be required to reduce 12.3 g of nitrobenzene to aniline if the current efficiency for the process is 50 percent. If the potential drop across the cell is 3 volts, how much energy will be consumed?

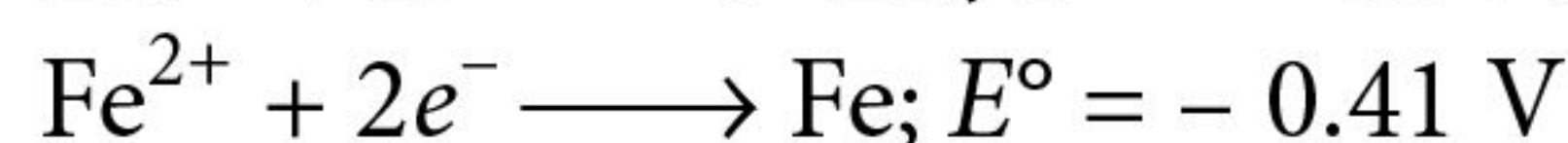
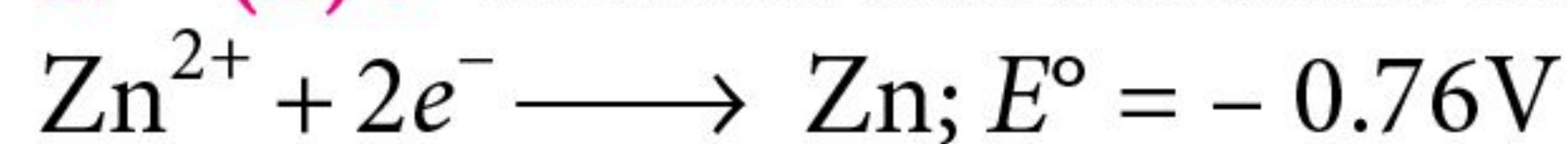
OR

- (B) (i) How many moles of mercury will be produced by electrolysis of 1.0 M $\text{Hg}(\text{NO}_3)_2$ solution with a current of 2.00 A for 3 hours?
- (ii) How many electrons flow through a metallic wire if a current of 0.5 A is passed for 2 hours?
(Given : 1 F = 96500 C mol⁻¹)

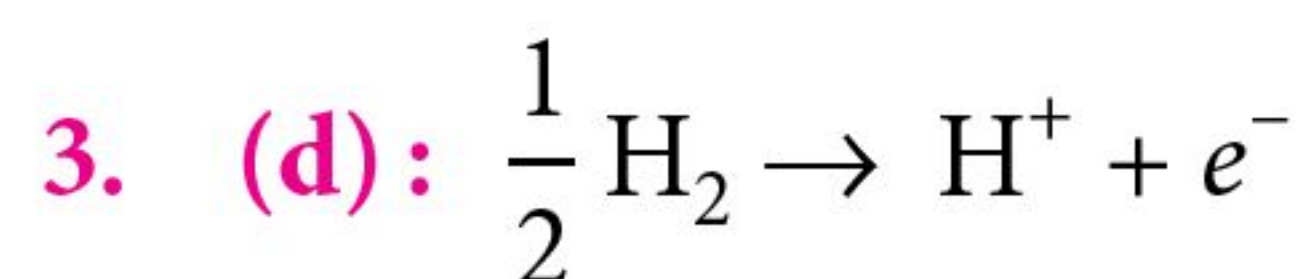
SOLUTIONS

1. (c)

2. (b) : The half cell reactions are



$$\begin{aligned} \therefore E_{\text{cell}}^\circ &= E_{\text{red (cathode)}}^\circ - E_{\text{red (anode)}}^\circ \\ &= -0.41 - (-0.76) = +0.35\text{V} \end{aligned}$$



$$\begin{aligned} E(\text{H}_2/\text{H}^+) &= E^\circ(\text{H}_2/\text{H}^+) - \frac{0.059}{n} \log [\text{H}^+] \\ &= 0 + \frac{0.059}{1} \times \text{pH} = 0.059 \times 10 = 0.59\text{V} \end{aligned}$$

4. (a) : $E_{\text{cell}}^\circ = E_{\text{A}^{2+}/\text{A}}^\circ - E_{\text{X}^{2+}/\text{X}}^\circ$
 $= [0.34 - (-2.37)]\text{V} = 2.71\text{V}$

5. (c) : The salt bridge possesses the electrolyte having nearly same ionic mobilities of its cation and anion.

6. (c) : For weak electrolyte, Λ_m first increases slowly and then rapidly with dilution but does not become constant.

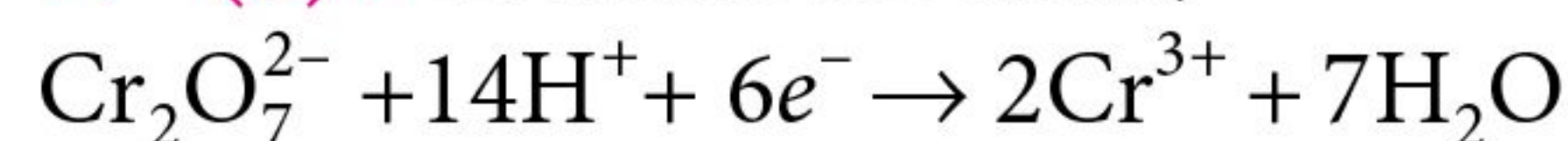
7. (b) : The standard Gibbs' energy
 $(\Delta G^\circ) = -nFE_{\text{cell}}^\circ$; Value of $n = 2$
 $\therefore \Delta G^\circ = -2 \times 96500 \times 0.24 = -46320\text{J} = -46.32\text{kJ/mol}$

8. (a) : $E_{\text{cell}}^\circ = \frac{0.0591}{2} \log K_C$

$$\log K_C = \frac{2 \times 0.46}{0.0591} = 15.56$$

$$K_C = \text{Antilog } 15.6$$

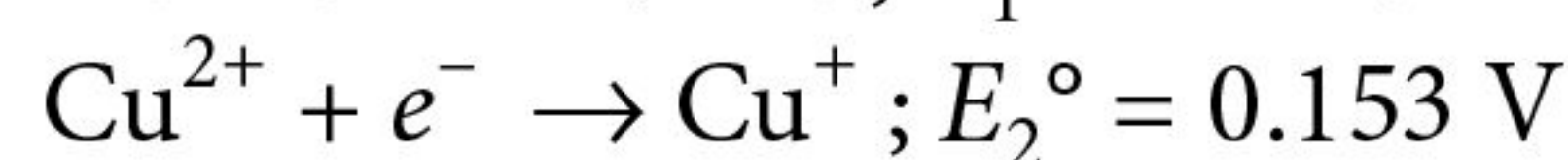
9. (d) : In acidic medium,



Thus, $n = 6$

Hence, 6 F charge is required to reduce 1 mol of $\text{Cr}_2\text{O}_7^{2-}$ to Cr^{3+} in acidic medium.

10. (d) : Given,



The required reaction is $\text{Cu}^+ + e^- \longrightarrow \text{Cu}; E_3^\circ = ?$

Applying, $\Delta G^\circ = -nFE^\circ$,

$$\Delta G_3^\circ = \Delta G_1^\circ - \Delta G_2^\circ \Rightarrow -(n_3FE_3^\circ) = -(n_1FE_1^\circ) - (-n_2FE_2^\circ)$$

$$\text{or } E_3^\circ = 2 \times E_1^\circ - E_2^\circ$$

$$\text{or } E_3^\circ = (2 \times 0.337) - 0.153 = 0.52\text{V}$$

11. (b) : $E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0591}{n} \log_{10} \left[\frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} \right]$

Higher the $\frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]}$ ratio, lower is the emf of cell.

(i) $\frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = 10$; (ii) $\log \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = 1$

(iii) $\log \frac{[\text{Zn}^{2+}]}{[\text{Cu}^{2+}]} = 0.1$

So, order is $E_3 > E_2 > E_1$.

12. (b) : At Anode : $\text{Cl}^- \longrightarrow 1/2\text{Cl}_2 + e^-$

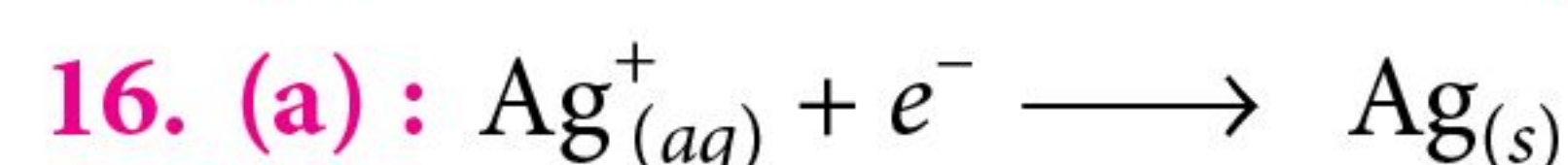
$$E_{\text{Cl}_2} = \frac{35.5 \times 2}{2} = 35.5$$

$$w_{\text{Cl}_2} = \frac{E_{\text{Cl}_2} \times I \times t}{96500} = \frac{35.5 \times 2 \times 30 \times 60}{96500} = 1.32\text{g}$$

13. (b) : In the plot of molar conductivity versus concentration, for weak electrolyte the extrapolation to zero concentration is not possible.

14. (a)

15. (a)



Charge on one mole of electrons

$$= 6.02 \times 10^{23} \times 1.6021 \times 10^{-19}$$

$$= 96487\text{C mol}^{-1} \approx 96500\text{C mol}^{-1}$$

17. (i) Electrolyte A is a strong electrolyte while electrolyte B is a weak electrolyte.

(ii) For electrolyte A, the plot becomes linear near high dilution and thus can be extrapolated to zero concentration to get the molar conductivity at infinite dilution.

18. (A) (a) This is because H^+ ions produced from ionization of water have lower discharge potential than Na^+ ions produced from ionization of NaCl or reduction potential of water is greater than that of sodium ions.

(b) The reactions at cathode for the deposit of Na and Al are



Thus, 1 faraday deposits 1 mol of Na whereas 3 faradays are required for depositing one mol of Al.

OR

(B) (a) The cell reaction may be split into two half reactions as :



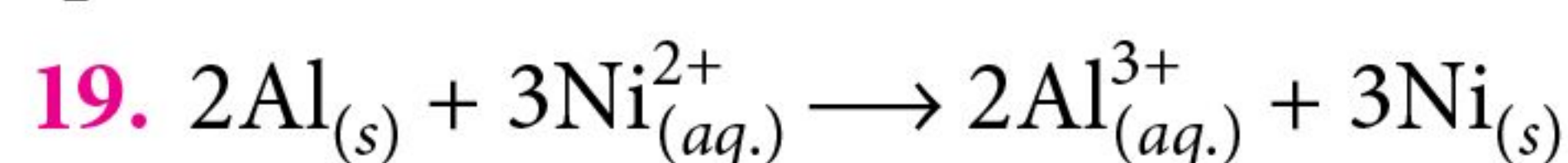
$$E_{\text{cell}}^{\circ} = E_{\text{Cathode}}^{\circ} - E_{\text{Anode}}^{\circ}$$

$$= +0.76 - (-0.80) \text{ volt} = 1.56 \text{ volts}$$

(b) Cell reaction : $2Fe^{2+} + Sn^{4+} \rightarrow 2Fe^{3+} + Sn^{2+}$

$$E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} = 0.15 - 0.771 = -0.621$$

Since E_{cell}° is negative hence, cell reaction is non-spontaneous.



$$E_{\text{cell}}^{\circ} = E_{Ni^{2+}/Ni}^{\circ} - E_{Al^{3+}/Al}^{\circ} = -0.25 - (-1.66) = 1.41 \text{ V}$$

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log \frac{[Al^{3+}]^2}{[Ni^{2+}]^3}$$

$$= 1.41 - \frac{0.0591}{6} \log \frac{(0.001)^2}{(0.1)^3} = 1.41 - \frac{0.0591}{6} \log 10^{-3}$$

$$= 1.41 + \frac{0.0591}{6} \times 3 \times 1 = 1.439 \text{ V}$$

20. (i) Mercury cell is used for low current devices like watches and hearing aids.

(ii) The hydrogen oxygen fuel cell was used in Apollo space programme.

(iii) Lead storage battery is used in automobiles and inverters.

(iv) Dry cell.

$$\mathbf{21.} \text{ Given, } \Lambda_{Ba(OH)_2}^{\circ} = \lambda_{Ba^{2+}}^{\circ} + 2\lambda_{OH^-}^{\circ} = 523.28 \quad \dots(i)$$

$$\Lambda_{BaCl_2}^{\circ} = \lambda_{Ba^{2+}}^{\circ} + 2\lambda_{Cl^-}^{\circ} = 280.0 \quad \dots(ii)$$

$$\Lambda_{NH_4Cl}^{\circ} = \lambda_{NH_4^+}^{\circ} + \lambda_{Cl^-}^{\circ} = 129.8 \quad \dots(iii)$$

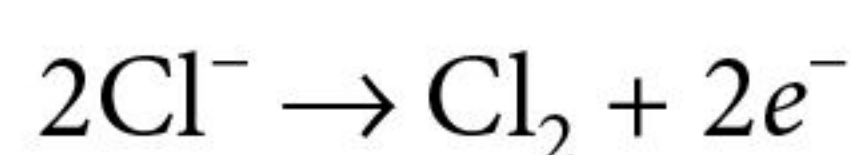
$$\Lambda_{NH_4OH}^{\circ} = \frac{\Lambda_{Ba(OH)_2}^{\circ} + 2\Lambda_{NH_4Cl}^{\circ} - \Lambda_{BaCl_2}^{\circ}}{2}$$

$$= \frac{523.28 + 2(129.8) - 280.0}{2} = 251.44 \text{ S cm}^2 \text{ mol}^{-1}$$

22. Y is a weak electrolyte. As the concentration of the weak electrolyte is reduced, more of it ionises. Hence, a weak electrolyte shows a very large increase in concentration with dilution. A strong electrolyte shows only small increase in conductance with dilution, because a strong electrolyte is completely dissociated in solution so the number of ions remain constant. A little increase in molar conductivity occurs due to reduced interionic attraction.

23. Quantity of electricity

$$Q = I \times t = \frac{300}{1000} \times 60 = 18 \text{ coulomb}$$



i.e., 2F (2×96500 coulomb) deposit 1 mole of chlorine

$$\therefore 18 \text{ coulomb will deposit} = \frac{1}{2 \times 96500} \times 18 \text{ mol } Cl_2$$

$$= \frac{1}{2 \times 96500} \times 18 \times 6.022 \times 10^{23} \text{ molecules of } Cl_2$$

$$= 5.617 \times 10^{19} \text{ } Cl_2 \text{ molecules.}$$

$$\mathbf{24.} \quad E_{\text{cell}}^{\circ} = E_{\text{right}}^{\circ} - E_{\text{left}}^{\circ} = -0.403 - (-0.763) = 0.36 \text{ V}$$

$$\Delta_r G^{\circ} = -nFE_{\text{cell}}^{\circ} = -2 \times 96500 \times 0.36$$

$$= -69480 \text{ J mol}^{-1} = -69.48 \text{ kJ mol}^{-1}$$

$$\text{Using formula, } \log K_c = \frac{nE_{\text{cell}}^{\circ}}{0.059} = \frac{2 \times 0.36}{0.059} = 12.20$$

$$K_c = \text{antilog } 12.20 = 1.58 \times 10^{12}$$

OR

The electrode reactions are



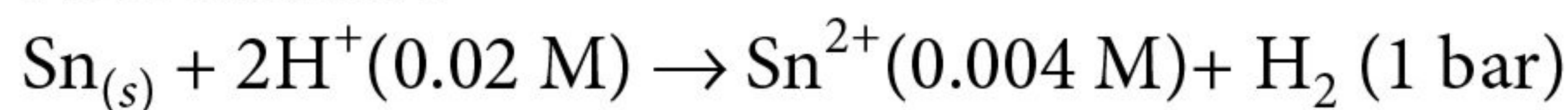
MONTHLY TEST DRIVE CLASS XI

ANSWER

KEY

1. (c)	2. (b)	3. (b)	4. (d)	5. (c)
6. (b)	7. (a)	8. (a)	9. (c)	10. (b)
11. (a)	12. (c)	13. (c)	14. (a)	15. (b)
16. (d)	17. (b)	18. (c)	19. (c)	20. (c,d)
21. (a,b,d)	22. (b,c)	23. (a,c)	24. (6)	25. (150)
26. (5)	27. (b)	28. (d)	29. (b)	30. (a)

Net reaction :



The Nernst equation of this cell at 25 °C

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{2} \log \frac{[\text{Sn}^{2+}](p_{\text{H}_2})}{[\text{H}^+]^2}$$

$$E_{\text{cell}}^{\circ} = E_{\text{H}^+|\text{H}_2}^{\circ} - E_{\text{Sn}^{2+}|\text{Sn}}^{\circ}$$

$$= 0.000 \text{ V} - (-0.14 \text{ V}) = +0.14 \text{ V}$$

$$\begin{aligned} \text{or, } E_{\text{cell}} &= E_{\text{cell}}^{\circ} - 0.02955 \log \frac{0.004 \times 1}{(0.02)^2} \\ &= E_{\text{cell}}^{\circ} - 0.02955 \log \left(\frac{0.004}{0.0004} \right) \\ &= E_{\text{cell}}^{\circ} - 0.02955 (\log 10) \\ &= E_{\text{cell}}^{\circ} - 0.02955 \times 1 = E_{\text{cell}}^{\circ} - 0.02955 \\ E_{\text{cell}} &= 0.14 - 0.02955 = 0.1104 \text{ V} \end{aligned}$$

$$\begin{aligned} 25. \Lambda_{eq} &= \kappa \times \frac{1000}{\text{Molarity}} = 4.23 \times 10^{-4} \times \frac{1000}{0.04} \\ &= 10.575 \text{ S cm}^2 \text{ mol}^{-1} \end{aligned}$$

$$\Lambda_m^{\circ} = 172.8 \text{ S cm}^2 \text{ mol}^{-1}$$

$$\text{Applying, } \alpha = \frac{\Lambda_m}{\Lambda_m^{\circ}} = \frac{10.575}{172.8} = 0.0612 = 6.12\%$$

26. The electrode reaction is $\text{H}^+ + e^- \rightarrow \frac{1}{2} \text{H}_2$
On applying Nernst equation,

$$E_{\text{H}^+/\text{H}_2} = E_{\text{H}^+/\text{H}_2}^{\circ} - \frac{0.0591}{1} \log \frac{1}{[\text{H}^+]} \quad (\because n=1)$$

$$-0.118 = 0 + 0.0591 \log [\text{H}^+]$$

As $\text{pH} = -\log[\text{H}^+]$, the equation becomes

$$\text{pH} = \frac{0.118}{0.0591} = 2$$

27. Charge = 24,000 coulombs

According to reaction, $\text{Cr}^{6+} + 6e^- \rightarrow \text{Cr}_{(s)}$

We require 6F or $6 \times 96500 \text{ C}$ to deposit 1 mole or 52 g of Cr.

For 24,000 C, the mass of Cr deposited

$$= \frac{52 \times 24,000}{6 \times 96500} = 2.15 \text{ g}$$

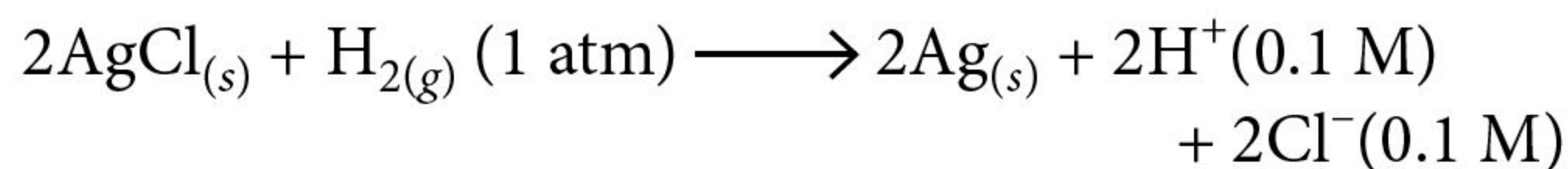
According to Faraday's first law of electrolysis, $w = ZIt$

$$1.5 = \frac{52}{6 \times 96500} \times 12.5 \times t$$

$$\Rightarrow t = \frac{6 \times 1.5 \times 96500}{52 \times 12.5} = 1336.15 \text{ s}$$

$$28. \Delta G^{\circ} = -nFE_{\text{cell}}^{\circ}$$

$$E_{\text{cell}}^{\circ} = \frac{\Delta G^{\circ}}{-nF} = \frac{-43600}{-2 \times 96500} = 0.226 \text{ V}$$



$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log \frac{[\text{Product}]}{[\text{Reactant}]}$$

$$= 0.226 - \frac{0.0591}{2} \log \frac{(0.1)^2}{(1)}$$

$$= 0.226 - \frac{0.0591}{2} \log (10^{-2}) = 0.226 - \frac{0.0591}{2} (-2)$$

$$= 0.226 + 0.0591 = 0.2851 \text{ V}$$

$$29. (a) \text{Zn} + \text{Fe}^{2+} \rightarrow \text{Fe} + \text{Zn}^{2+}; E = E^{\circ} - \frac{0.0591}{n} \log K_C.$$

Given $E = 0.2905 \text{ V}$

$$\text{i.e. } 0.2905 = E^{\circ} - \frac{0.059}{2} \log \frac{0.01}{0.001}$$

$$\text{or, } E^{\circ} = 0.2905 + 0.0295 \log 10$$

$$= 0.2905 + 0.0295 = 0.32 \text{ V} \quad (\because \log 10 = 1)$$

$$E^{\circ} = \frac{0.0591}{n} \log K_{eq} \quad \text{or, } 0.32 = \frac{0.0591}{2} \log K_{eq}$$

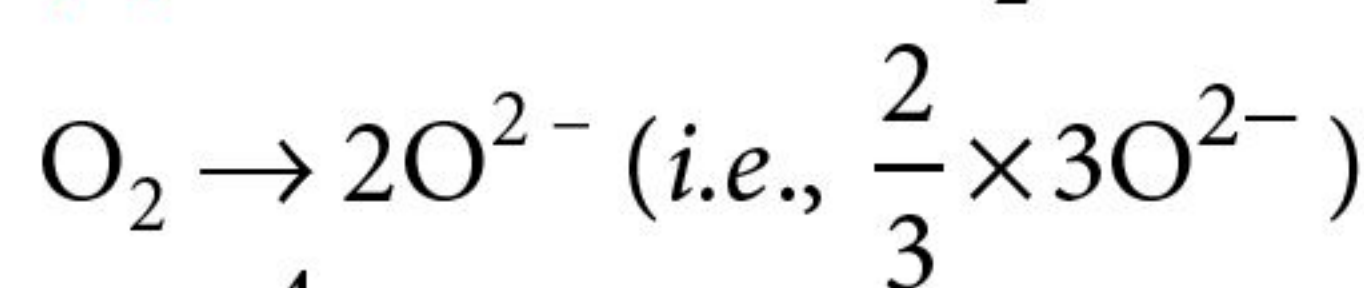
$$\therefore K_{eq} = 10^{0.32/0.0295} = 6.92 \times 10^{10}$$

$$(b) E_{\text{cell}}^{\circ} = \frac{0.059}{n} \log K$$

$$\text{or } \log K = \frac{1.10 \times 2}{0.059} = 37.2881 \quad \text{or } K = 1.9 \times 10^{37}$$

OR

(b) For 1 mole of O_2



or, $\frac{4}{3}$ mol of Al to change into Al^{3+} ions.

$$\therefore n = 4. \text{ Thus } \Delta G = -nFE^{\circ}$$

$$\therefore E^{\circ} = -\frac{\Delta G}{nF} = \frac{-827000}{4 \times 96500} = 2.14 \text{ volt.}$$

$$(c) E = E^{\circ} - \frac{0.0591}{n} \log Q \text{ at } 25^{\circ}\text{C}$$

At equilibrium, $E = 0$, $Q = K$

$$0 = E^{\circ} - \frac{0.0591}{n} \log K \quad \text{or, } K = \text{antilog} \left[\frac{nE^{\circ}}{0.0591} \right]$$

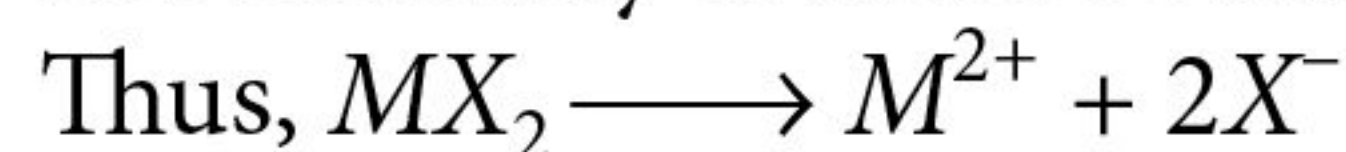
$$\text{or, } K = \text{antilog} \left[\frac{2 \times 0.295}{0.0591} \right] = \text{antilog} \left[\frac{0.590}{0.0591} \right]$$

$$= \text{antilog } 10 = 1 \times 10^{10}$$

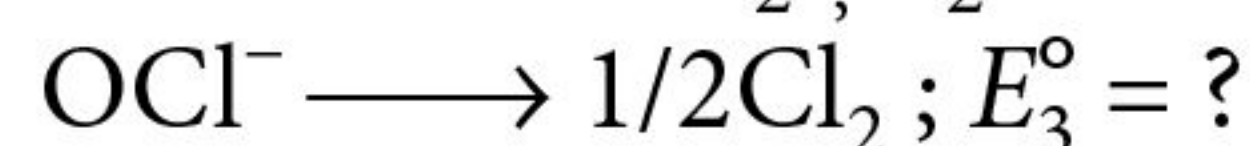
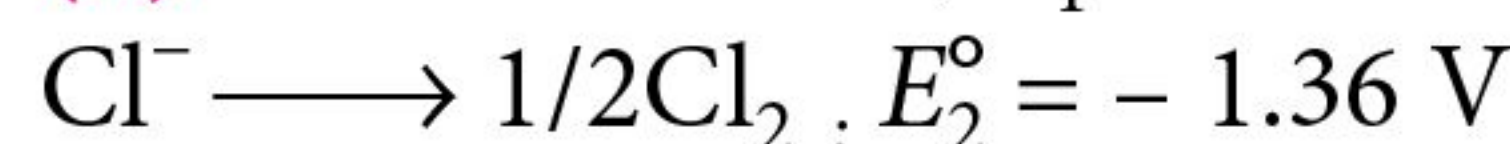
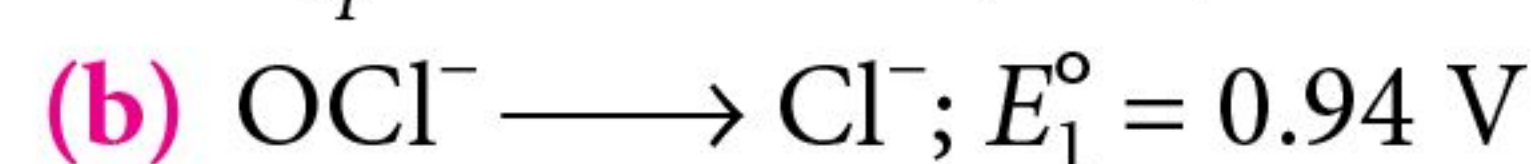
$$30. (a) 0.059 = \frac{0.059}{2} \log \frac{0.001}{[M^{2+}]} \quad [\because E_{\text{cell}} = 0.059 \text{ V}]$$

$$\log \frac{0.001}{[M^{2+}]} = 2 \quad \text{or } [M^{2+}] = 10^{-5} \text{ mol L}^{-1}$$

Let solubility of salt be s mol/litre.



$$\therefore K_{sp} = 4s^3 = 4 \times (10^{-5})^3 = 4 \times 10^{-15} \text{ mol}^3 \text{ L}^{-3}$$



Applying, $\Delta G^\circ = -nFE^\circ$

$$\Delta G_3^\circ = \Delta G_1^\circ + \Delta G_2^\circ$$

$$-n_3FE_3^\circ = (-n_1FE_1^\circ) + (-n_2FE_2^\circ)$$

$$n_1 = 2, n_2 = 1, n_3 = 1 - n_3E_3^\circ = -(n_1E_1^\circ + n_2E_2^\circ)$$

$$E_3^\circ = ((2 \times 0.94) - 1.36) \text{ V}$$

$$E_3^\circ = 0.52 \text{ V}$$

$$\begin{aligned} \text{(c)} \quad \Delta G &= -nFE_{\text{cell}} = -2 \times 96500 \times 0.059 \\ &= -11387 \text{ J mol}^{-1} \approx -11.4 \text{ kJ mol}^{-1} \end{aligned}$$

OR

(c) For the given cell $E_{\text{cell}}^\circ = 0$

So, equilibrium constant, $K_c = 0$

31. (A) (i) Here, conductivity (κ) = $0.146 \times 10^{-3} \text{ S cm}^{-1}$, resistance (R) = 1500Ω

$$\text{Cell constant} = \frac{\text{Conductivity}}{\text{Conductance}}$$

= Conductivity $\times$ Resistance

$$= \kappa \times R \quad \left[\because \text{conductance} = \frac{1}{\text{resistance}} \right]$$

$$= 0.146 \times 10^{-3} \times 1500 = 0.219 \text{ cm}^{-1}$$

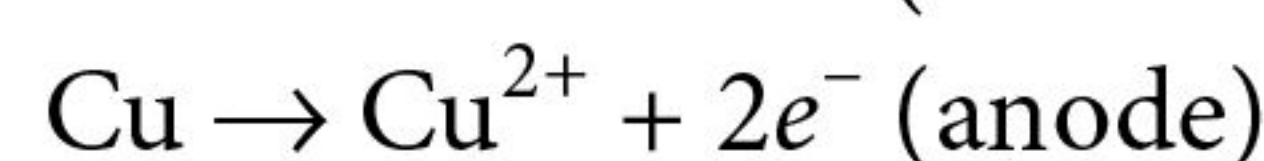
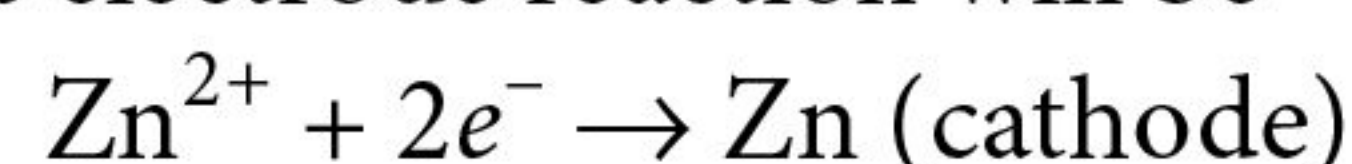
$$\text{(ii) Degree of dissociation, } \alpha = \frac{\Lambda_m}{\Lambda_m^\circ}$$

$$= \frac{11.7 \text{ S cm}^2 \text{ mol}^{-1}}{(49.9 + 349.1) \text{ S cm}^2 \text{ mol}^{-1}} = \frac{11.7}{399} = 3 \times 10^{-2}$$

OR

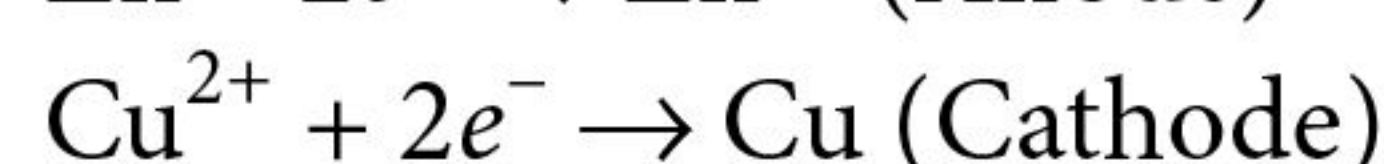
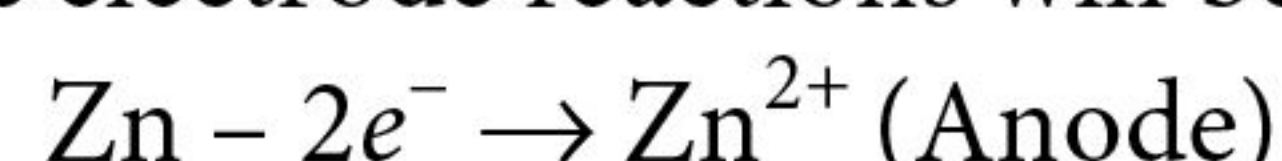
(B) (i) Cell B will act as electrolytic cell as it has lower emf.

The electrode reaction will be



(ii) With the values of emf, cell B will act as galvanic cell due to higher emf and will push electrons into cell A.

The electrode reactions will be



UNSCRAMBLE ME

Unscramble the words given in column I and match them with their explanations in column II.

Column I

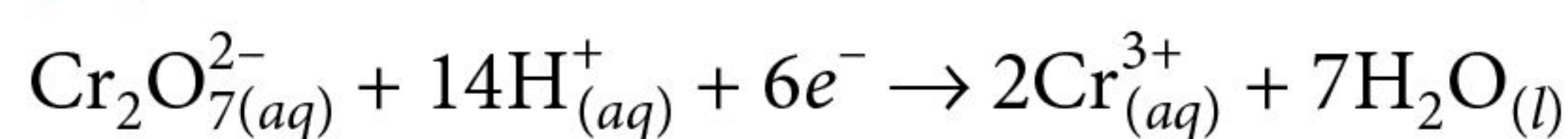
- DDOOCIIATNLY
- EERSIDC
- IINNULS
- EEMNSYZ
- LLAORECCFI
- TTEERG
- TLOSKE
- NNSSIIFOU
- RRCCMEIU
- OIGLD

Column II

- It is the hormone, secreted by the islets of Langerhans in the pancreas, which maintains the balance of glucose metabolism.
- They are the dilute solutions containing the water soluble components of vegetable drugs prepared by aqueous extraction of the drugs.
- It is a type of reaction of two or more unsaturated groups to give a new ring e.g., Diels-Alder addition.
- It is the constituent of vitamin D.
- These are the chemicals used to break snow or ice, especially in aircraft.
- It is the trivial name for diethyleneglycol.
- They are the class of proteins which catalyse reactions with a high degree of specificity and efficiency.
- It is a chemical used for removing impurities from gases.
- They are the organic compounds containing both a keto and an alcohol group.
- It is the compound of mercury in (II) oxidation state.

Readers can send their responses at editor@mtg.in or post us with complete address by 10th of every month. Winners' names and answers will be published in next issue.

(iii) For half cell reaction,



$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log \frac{[\text{Cr}^{3+}]^2}{[\text{Cr}_2\text{O}_7^{2-}][\text{H}^+]^{14}}$$

Given, $E_{\text{cell}}^{\circ} = 1.33 \text{ V}$, $n = 6$, $[\text{Cr}^{3+}] = 0.20 \text{ M}$

$[\text{Cr}_2\text{O}_7^{2-}] = 0.1 \text{ M}$, $[\text{H}^+] = 1 \times 10^{-4} \text{ M}$

$$\Rightarrow E_{\text{cell}} = 1.33 \text{ V} - \frac{0.0591}{6} \log \frac{(0.20)^2}{(0.1)(10^{-4})^{14}}$$

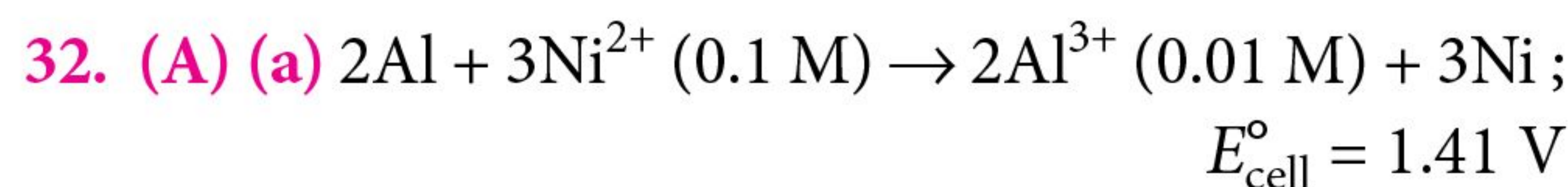
$$= 1.33 \text{ V} - \frac{0.0591}{6} \log (4 \times 10^{55})$$

$$= 1.33 \text{ V} - \frac{0.0591}{6} [\log 4 + \log 10^{55}]$$

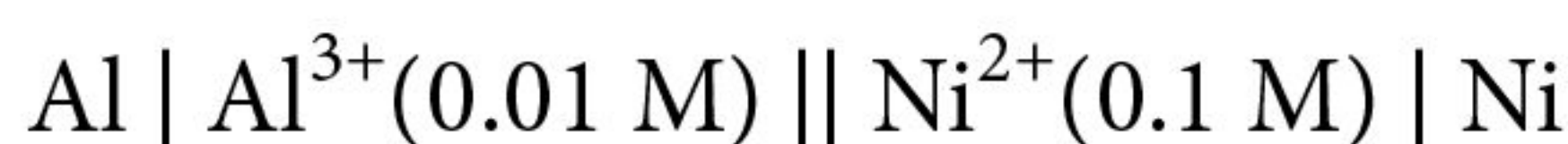
$$= 1.33 \text{ V} - \frac{0.0591}{6} [\log 4 + 55 \log 10]$$

$$= 1.33 \text{ V} - \frac{0.0591}{6} [0.602 + 55]$$

$$= 1.33 \text{ V} - 0.548 \text{ V} = 0.782 \text{ V}$$



The cell can be represented as :



$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log \frac{[\text{Al}^{3+}]^2}{[\text{Ni}^{2+}]^3}$$

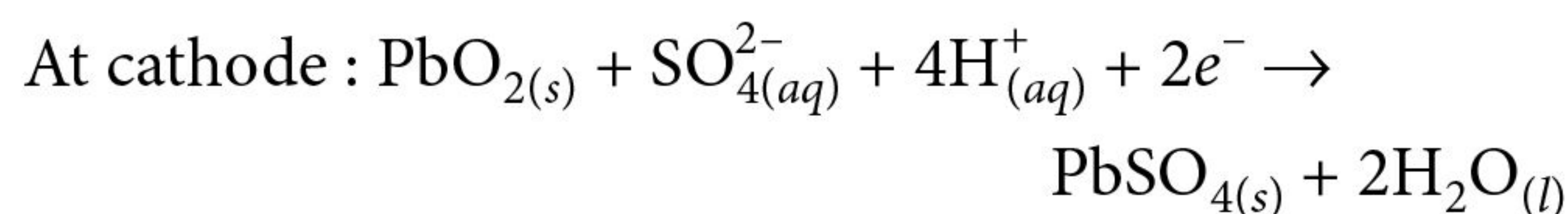
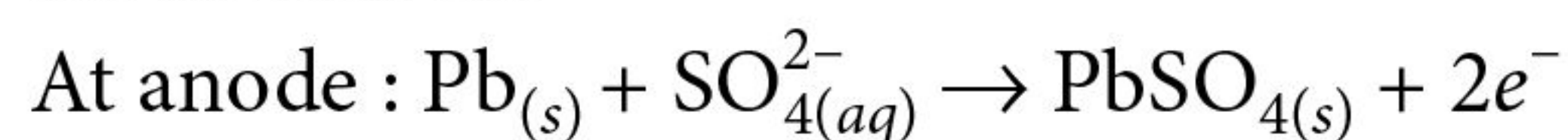
$$= 1.41 - \frac{0.0591}{n} \log \frac{(0.01)^2}{(0.1)^3}$$

$$= 1.41 - \frac{0.0591}{6} \log 10^{-1}$$

$$= 1.41 + \frac{0.0591}{6} = 1.419 \text{ V}$$

(b) Lead storage battery is a secondary cell.

Cell reactions for the given cell during its discharging are as follows:



Overall cell reaction :



OR

(B) $E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.0591}{n} \log \frac{[\text{Mg}^{2+}]}{[\text{Cu}^{2+}]}$

$$= 2.71 - \frac{0.0591}{2} \log \frac{0.001}{0.01} = 2.73955 \text{ V}$$

(i) If external opposing potential is less than 2.71 V then current will flow from Cu to Mg.

(ii) If external opposing potential is greater than 2.71 V then current will flow in opposite direction i.e., from Mg to Cu.

33. (A)(i) Quantity of electricity flowing through the cross-section of the wire per second = $1 \text{ A} \times 1 \text{ sec}$
 $= 1 \text{ coulomb}$

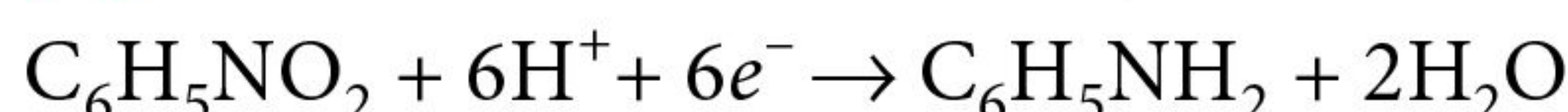
1 Faraday is equivalent to flow 1 mole of electron

i.e. 6.02×10^{23} electrons.

1 C will be equivalent to flow of electrons

$$= \frac{6.02 \times 10^{23}}{96500} = 6.24 \times 10^{18}$$

(ii) The reduction reaction may be written as :



Thus, 1 mol of $\text{C}_6\text{H}_5\text{NO}_2$ i.e., 123 g require electricity

$$= 6 \times 96500 \text{ C} = 579000 \text{ C}$$

$$12.3 \text{ g require electricity} = 57900 \text{ C}$$

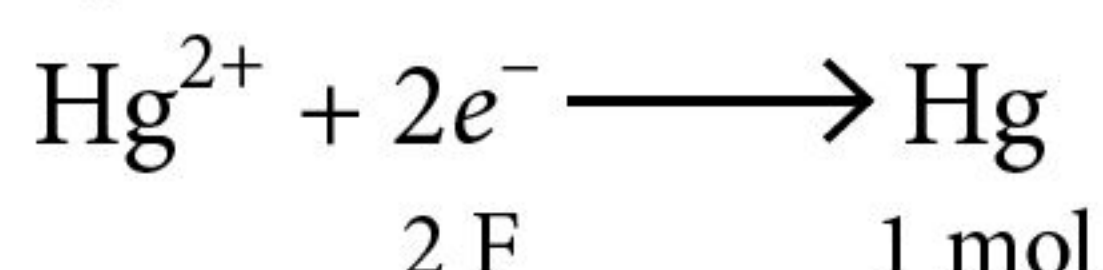
As the current efficiency is 50%, quantity of electricity actually required = $2 \times 57900 \text{ C} = 115800 \text{ C}$

$$\text{Energy consumed} = \text{EMF} \times \text{Quantity of electricity} \\ = 3 \times 115800 \text{ J} = 347400 \text{ J}$$

OR

(B) (i) Quantity of electricity passed

$$Q = I \times t = 2.0 \text{ A} \times 3 \times 60 \times 60 \text{ s} = 21600 \text{ C}$$



$2 \times 96500 \text{ C}$ electricity produces 1 mole Hg

$$\therefore 21600 \text{ C will produce} = \frac{21600}{2 \times 96500} \\ = 0.112 \text{ mole of Hg}$$

(ii) Given, $I = 0.5 \text{ A}$, $t = 2 \text{ hrs}$.

Number of electrons = ?

$$\text{Total charge (Q)} = I \times t = 0.5 \times 2 \times 60 \times 60 = 3600 \text{ C}$$

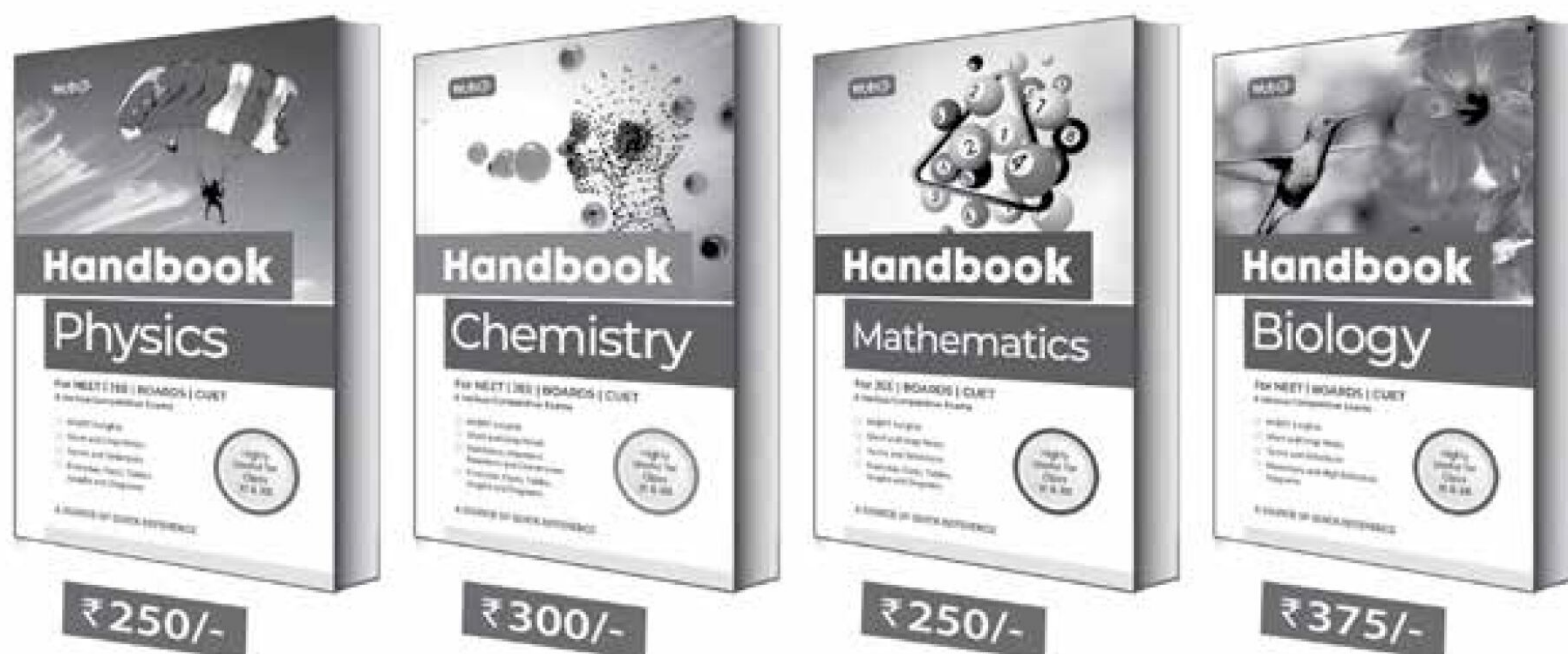
$\therefore$ Number of electrons

$$= \frac{\text{Total charge}}{\text{Charge of one electron}} = \frac{3600}{1.6 \times 10^{-19}} \\ = 2.25 \times 10^{22} \text{ electrons}$$



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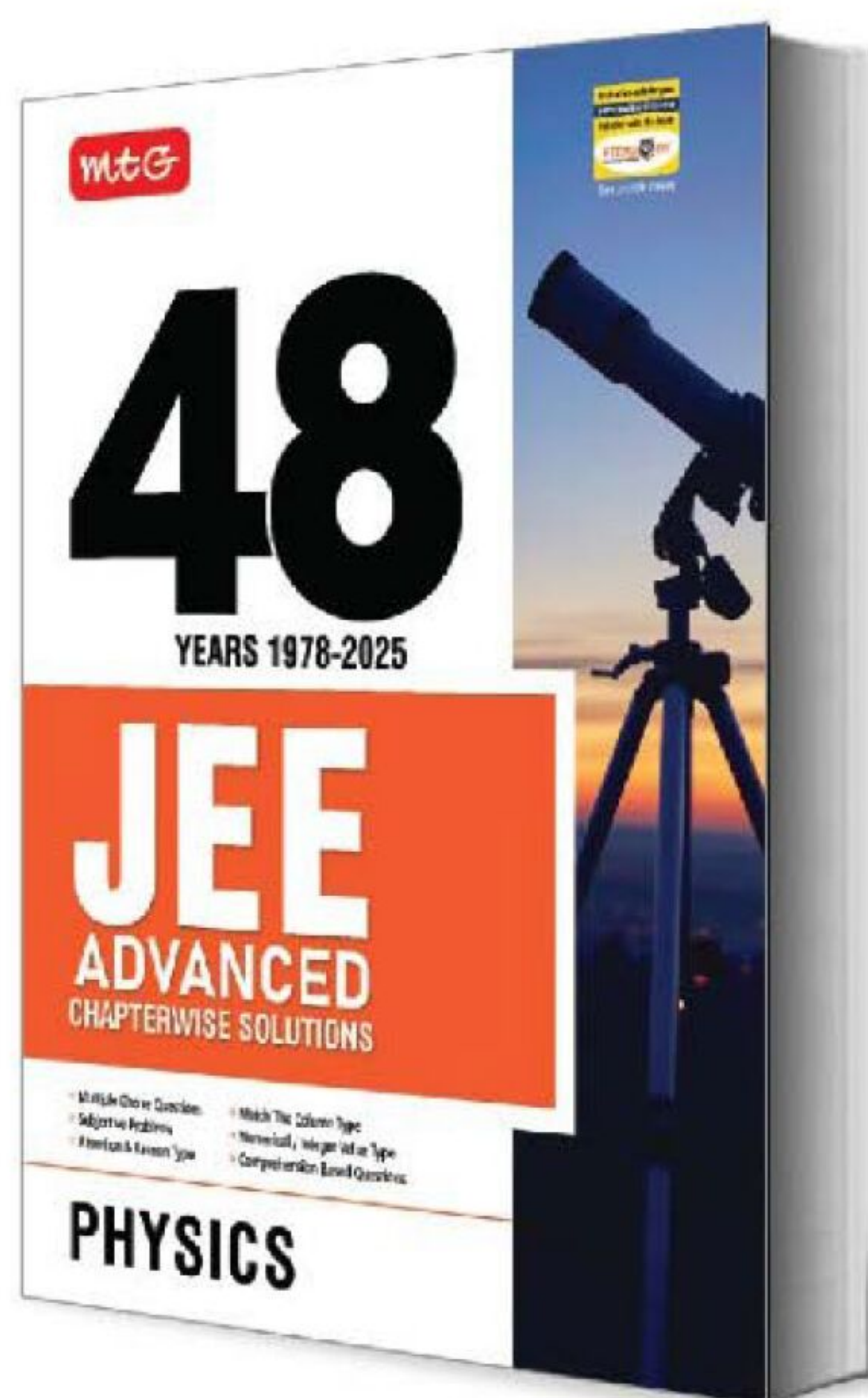
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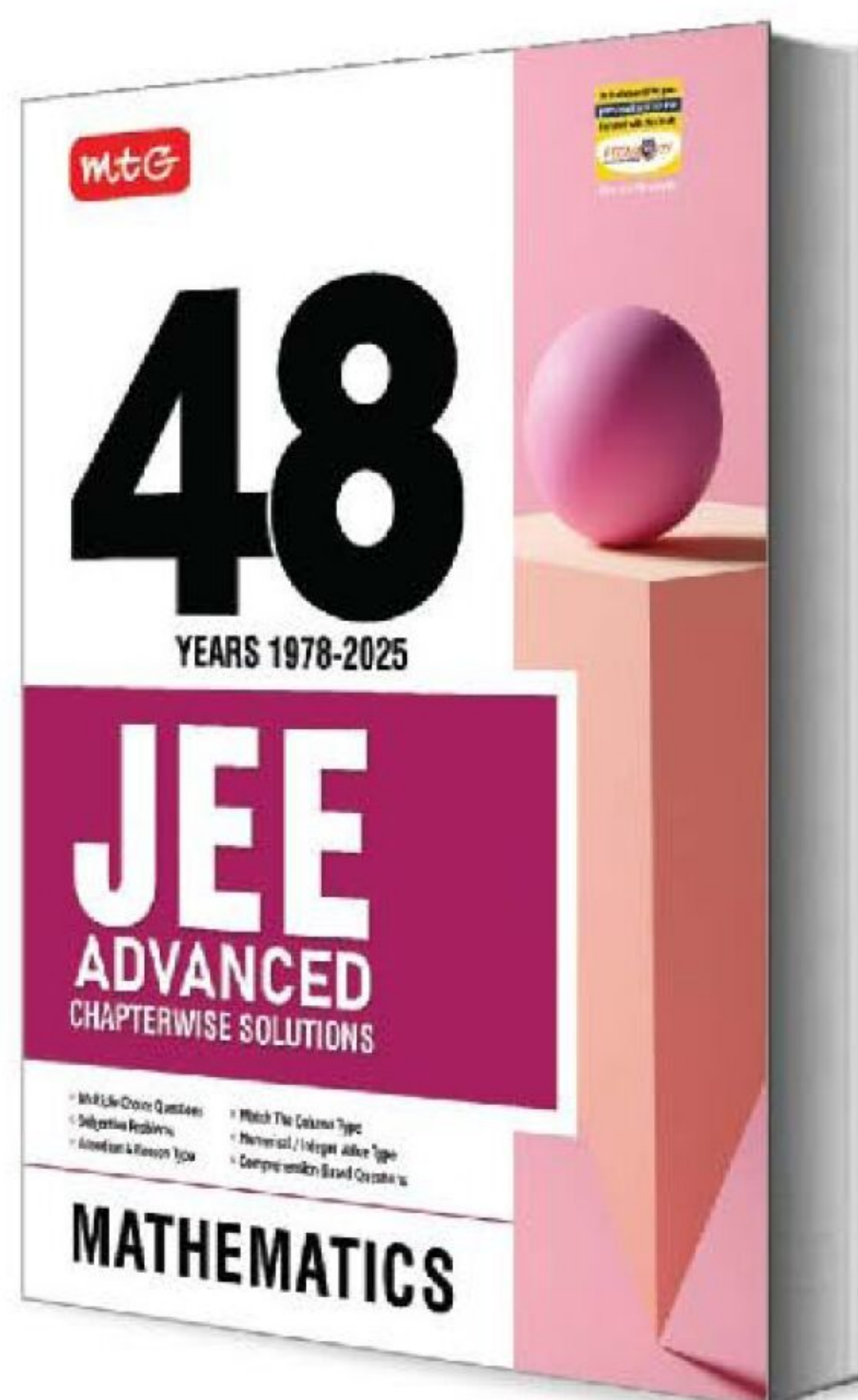
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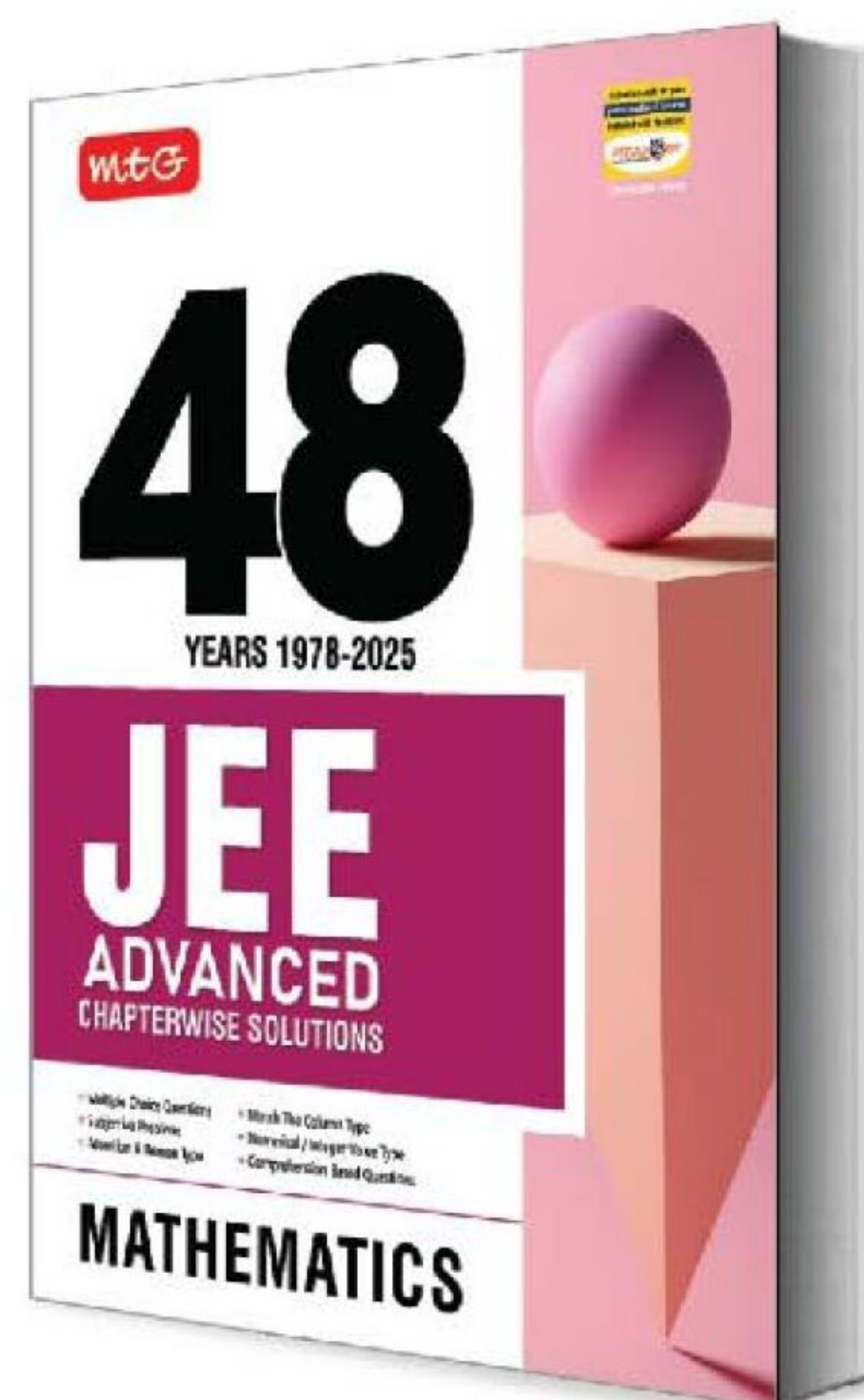
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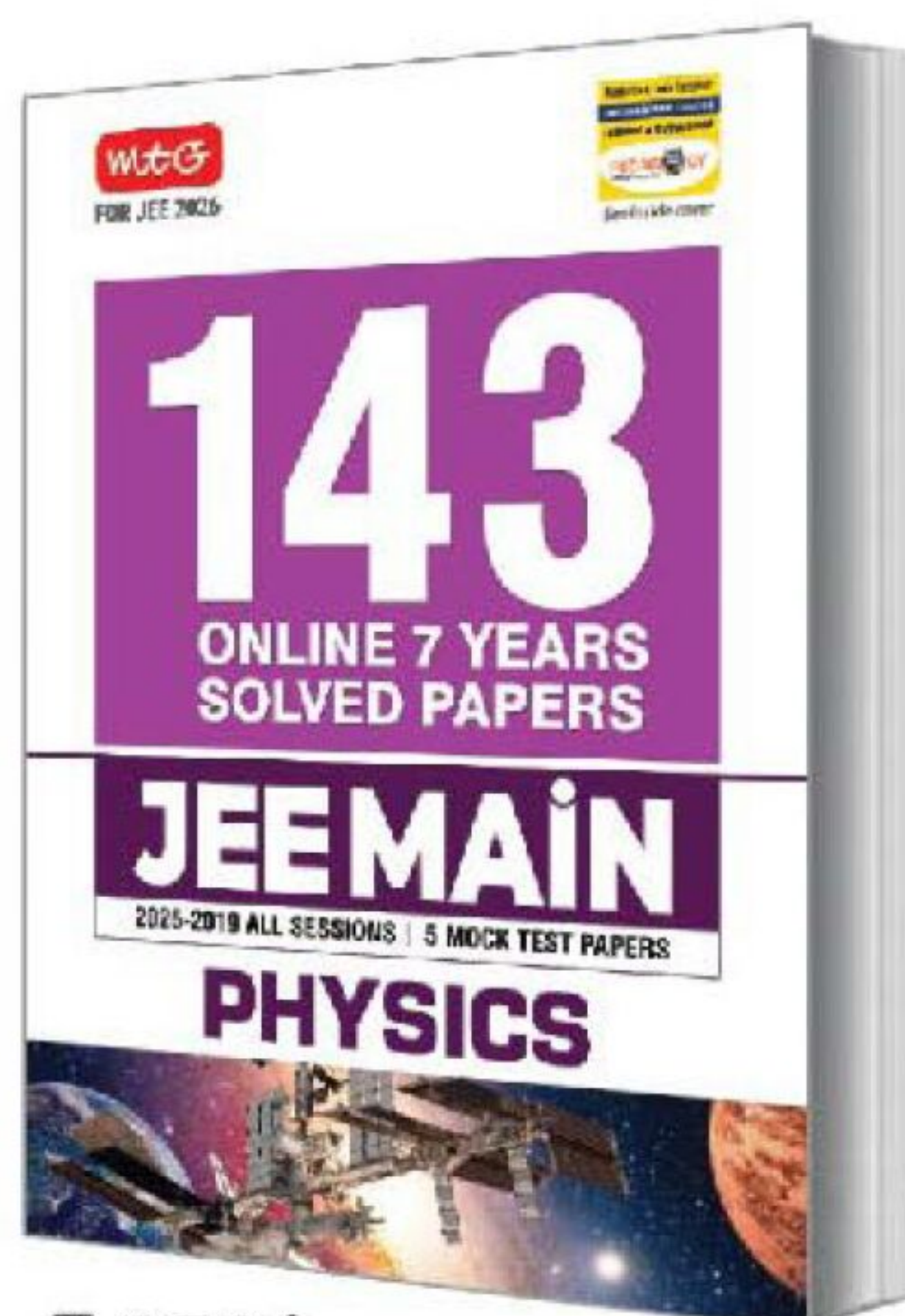
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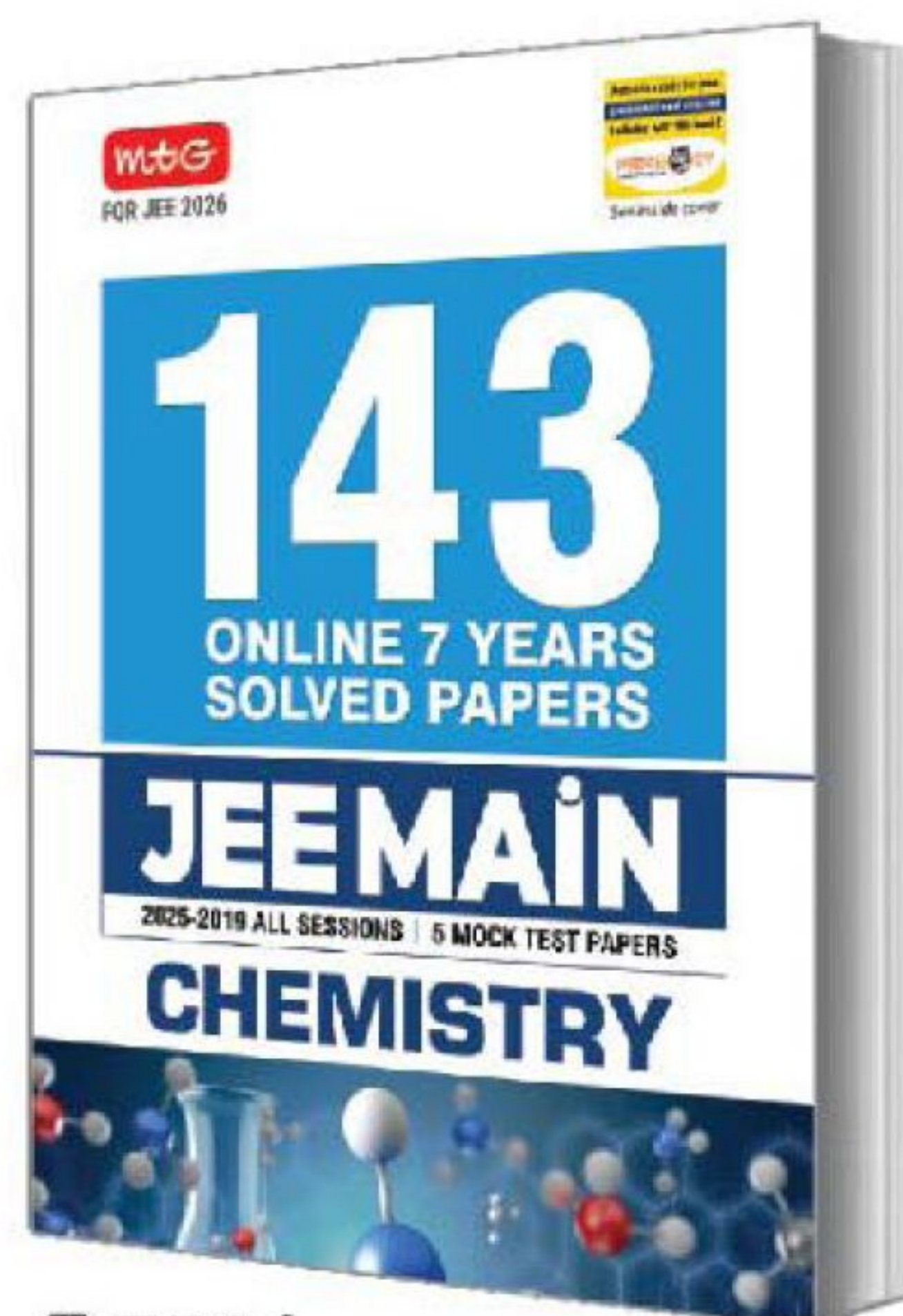
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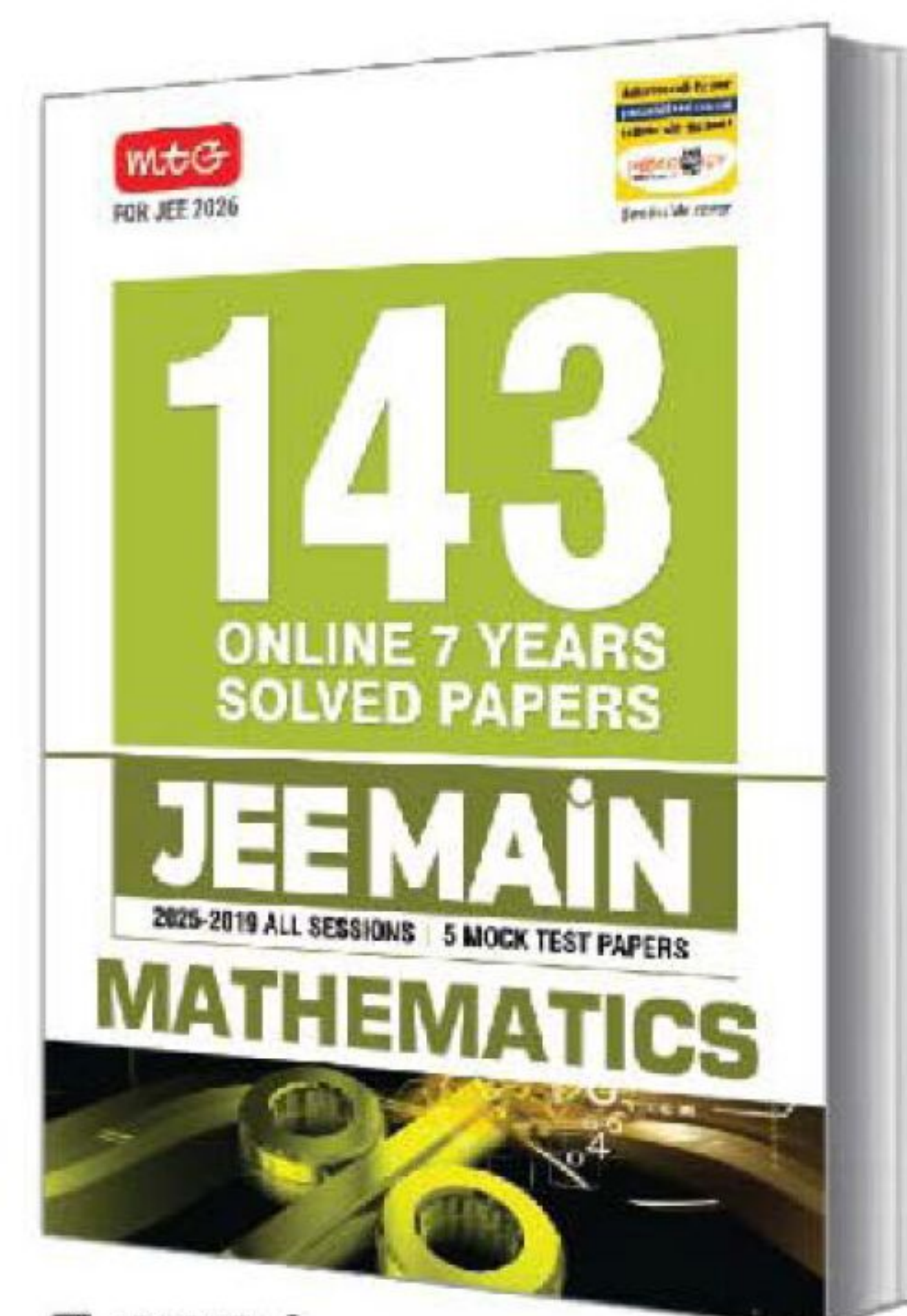
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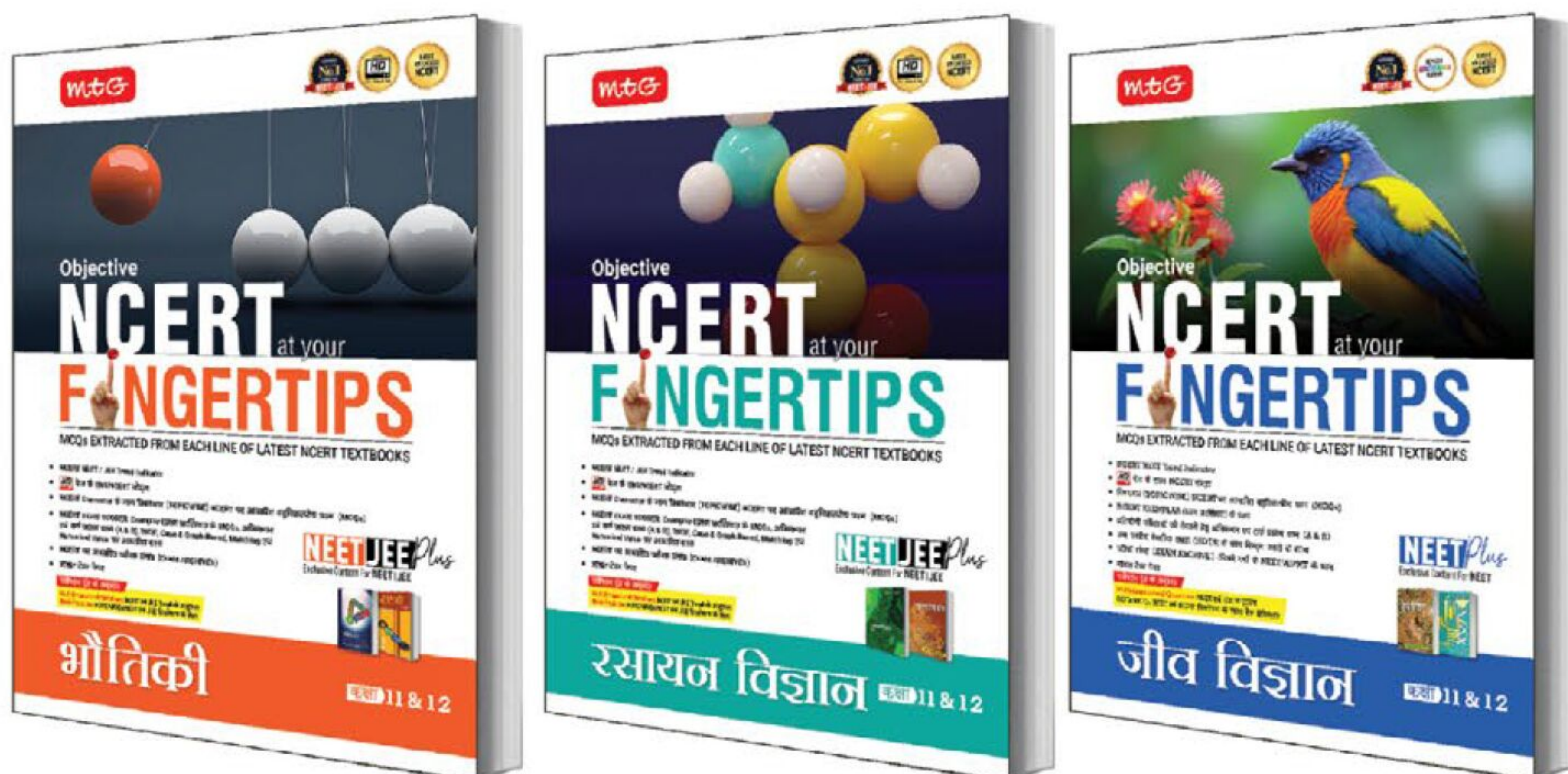


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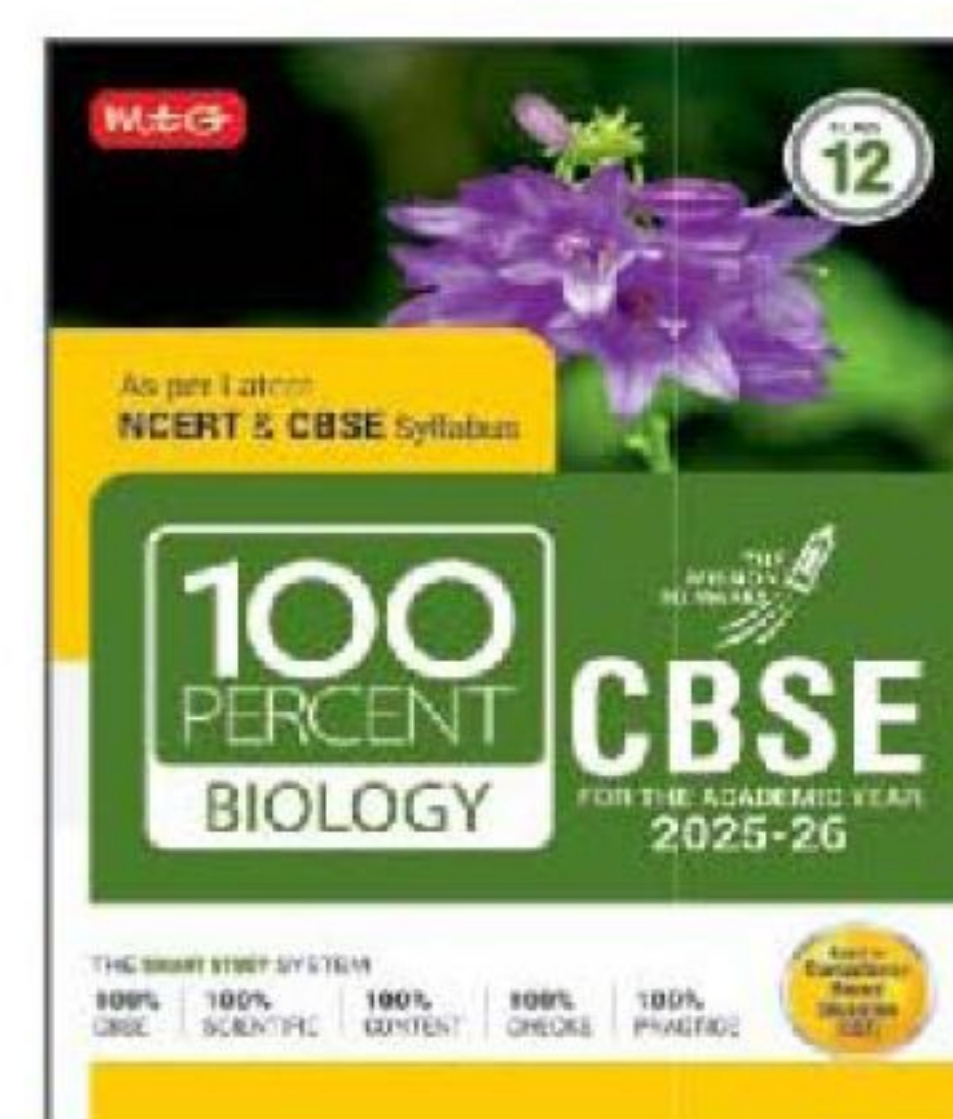
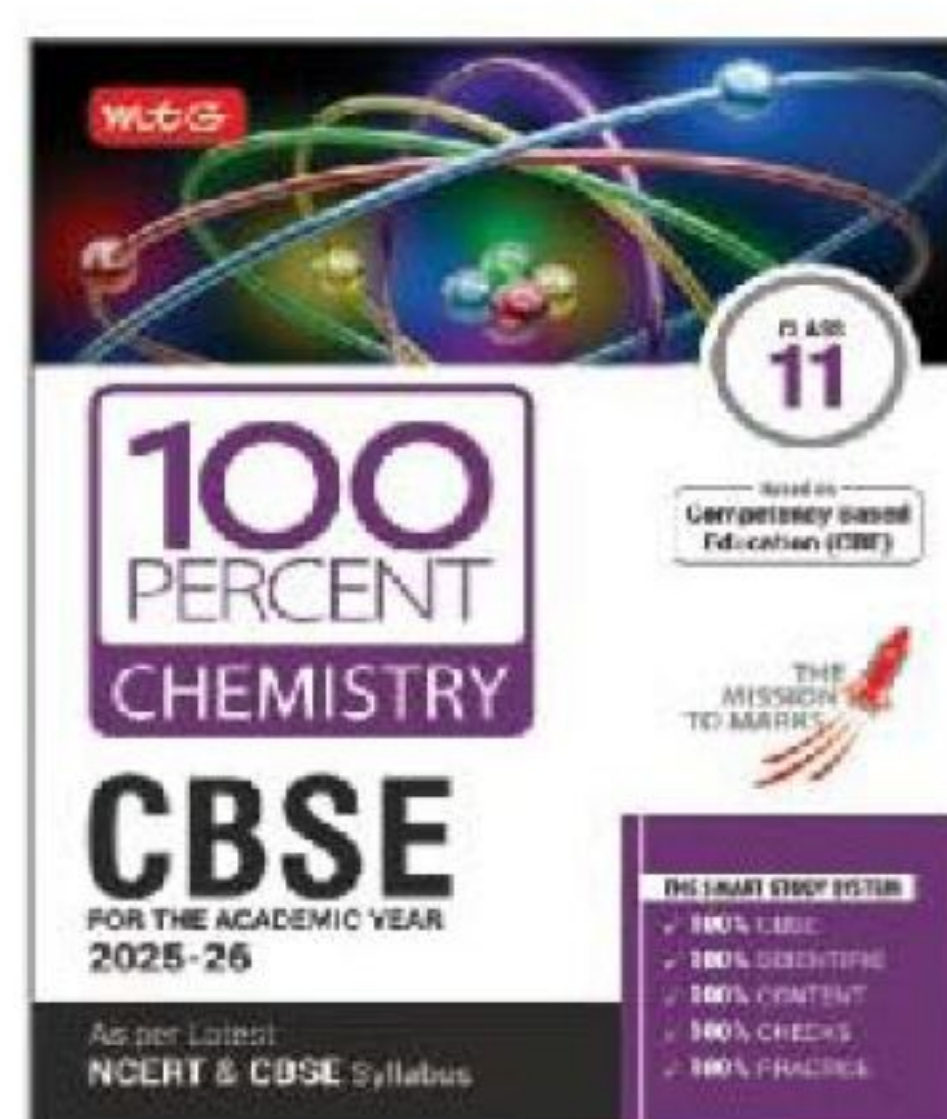
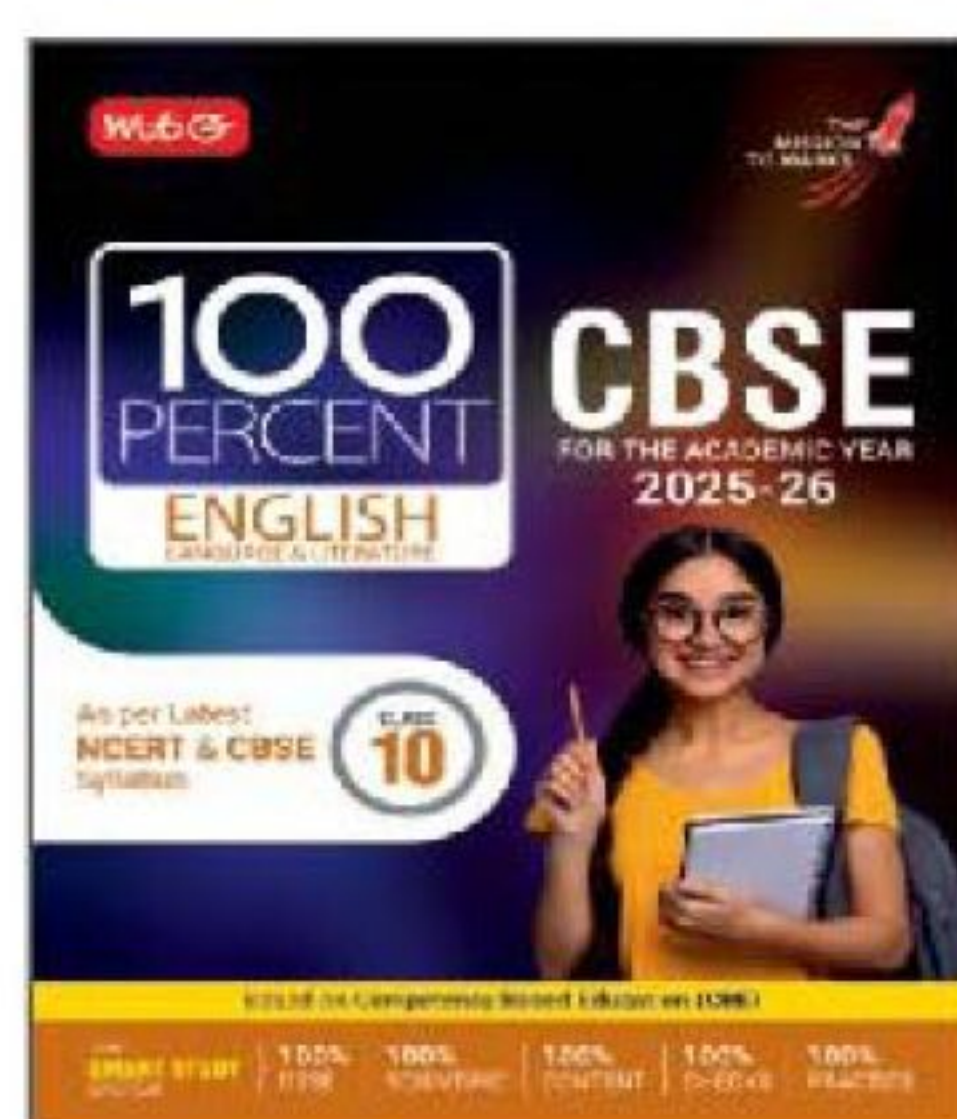
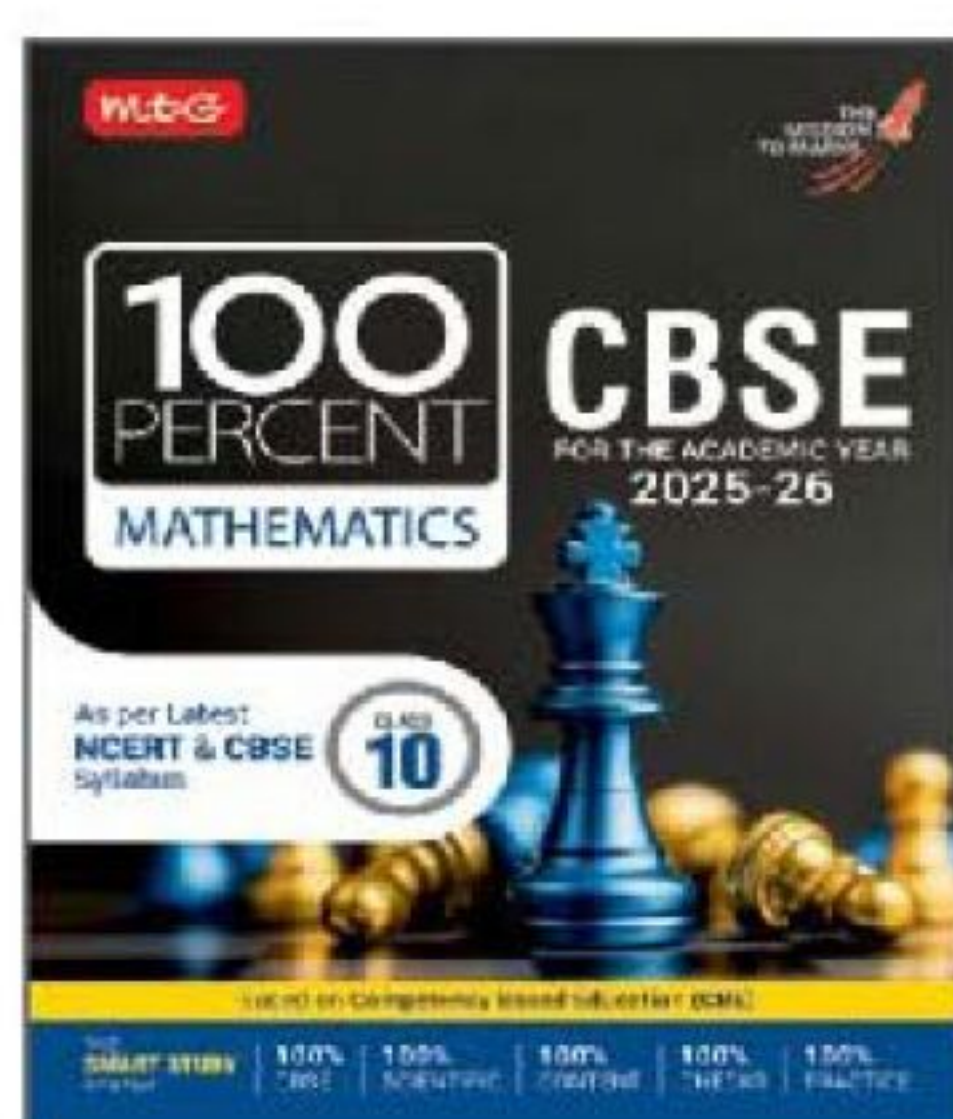
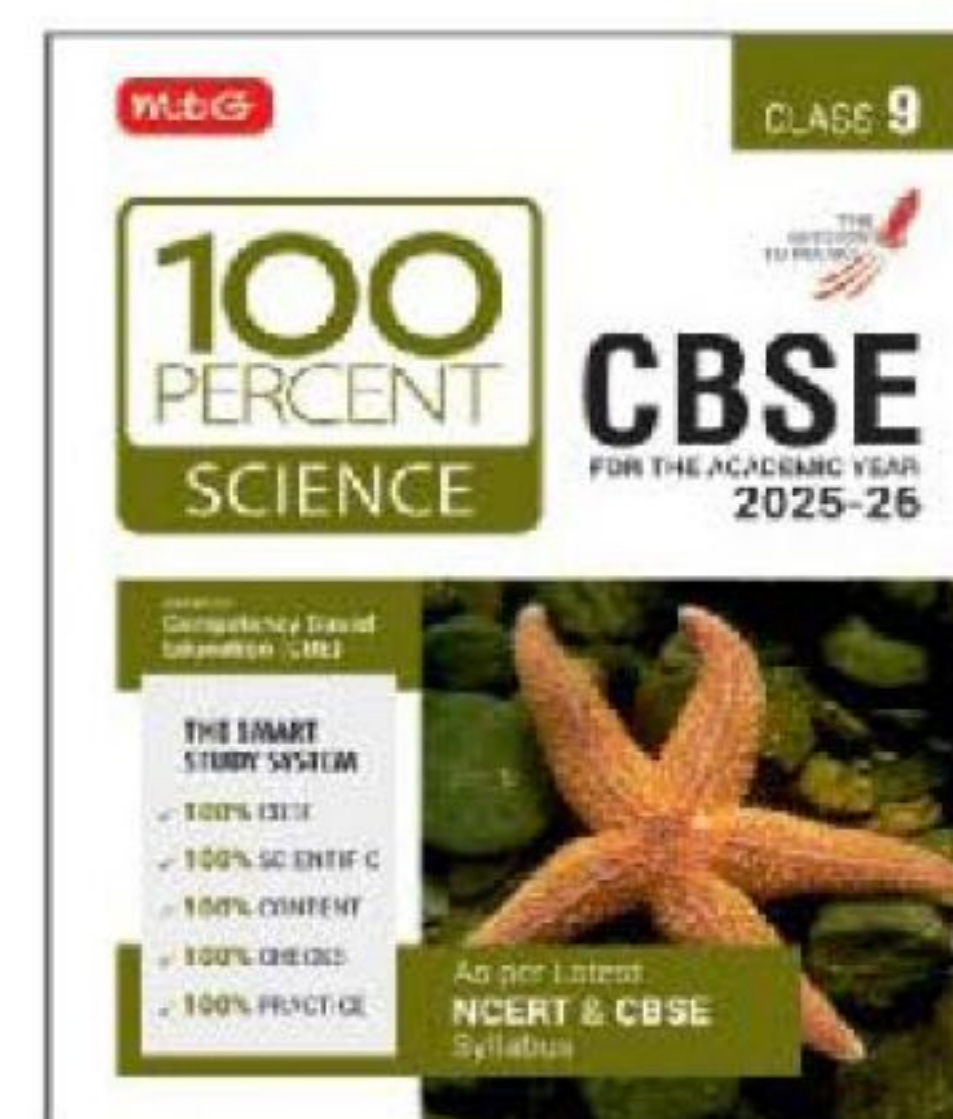
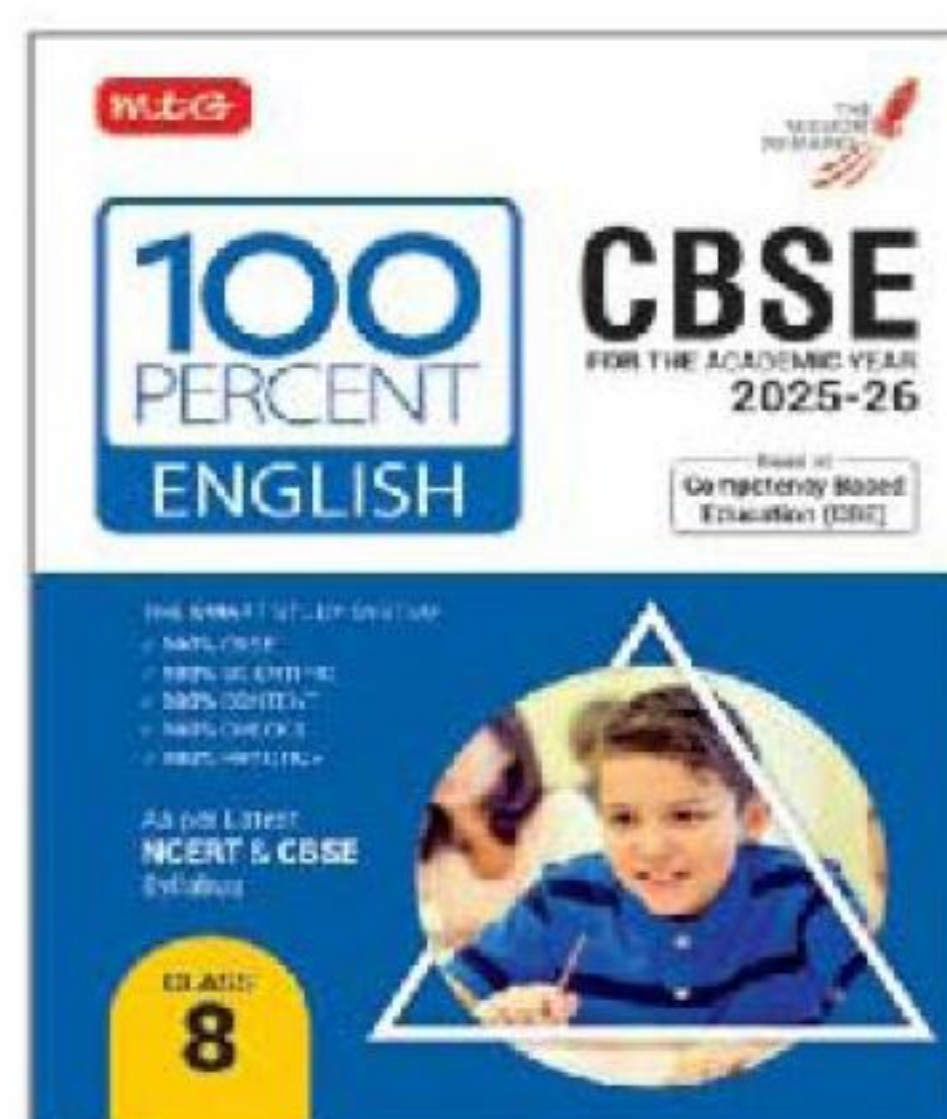
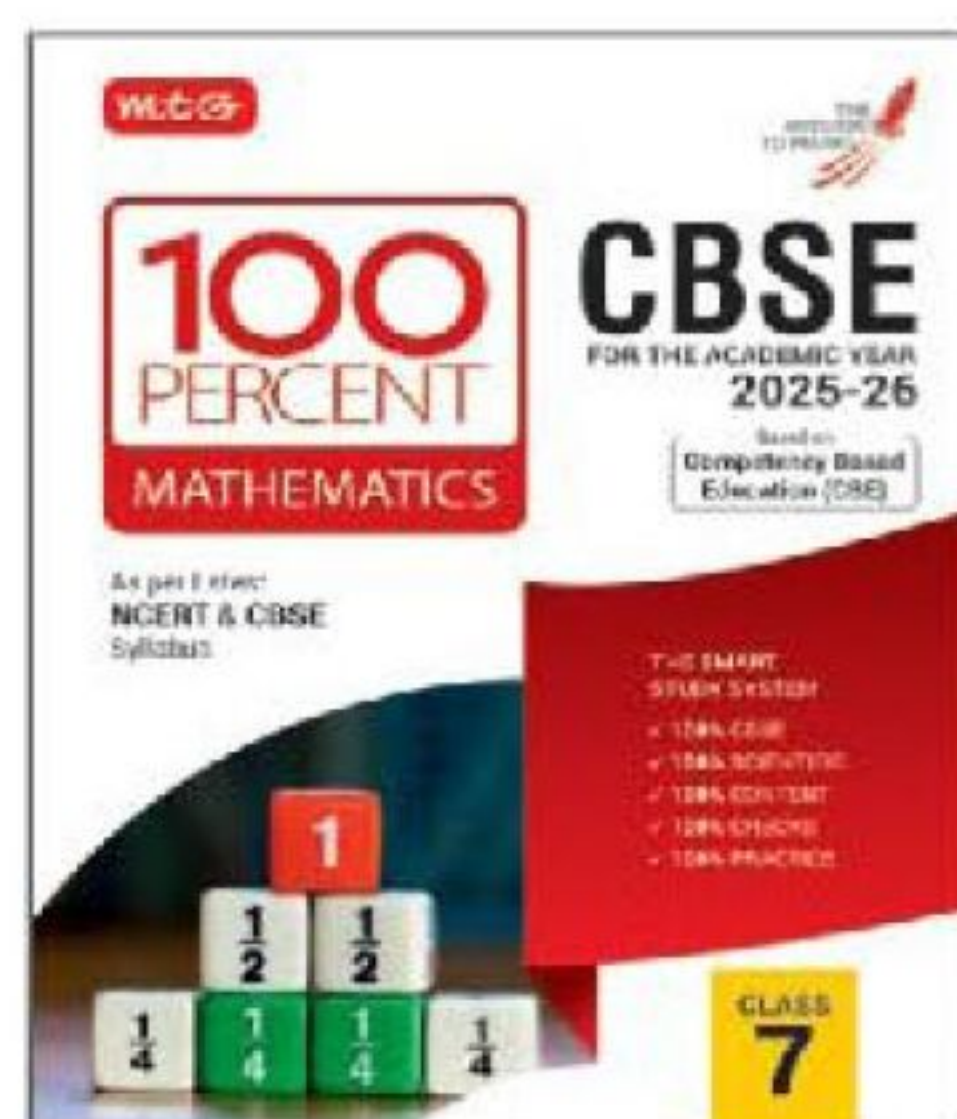
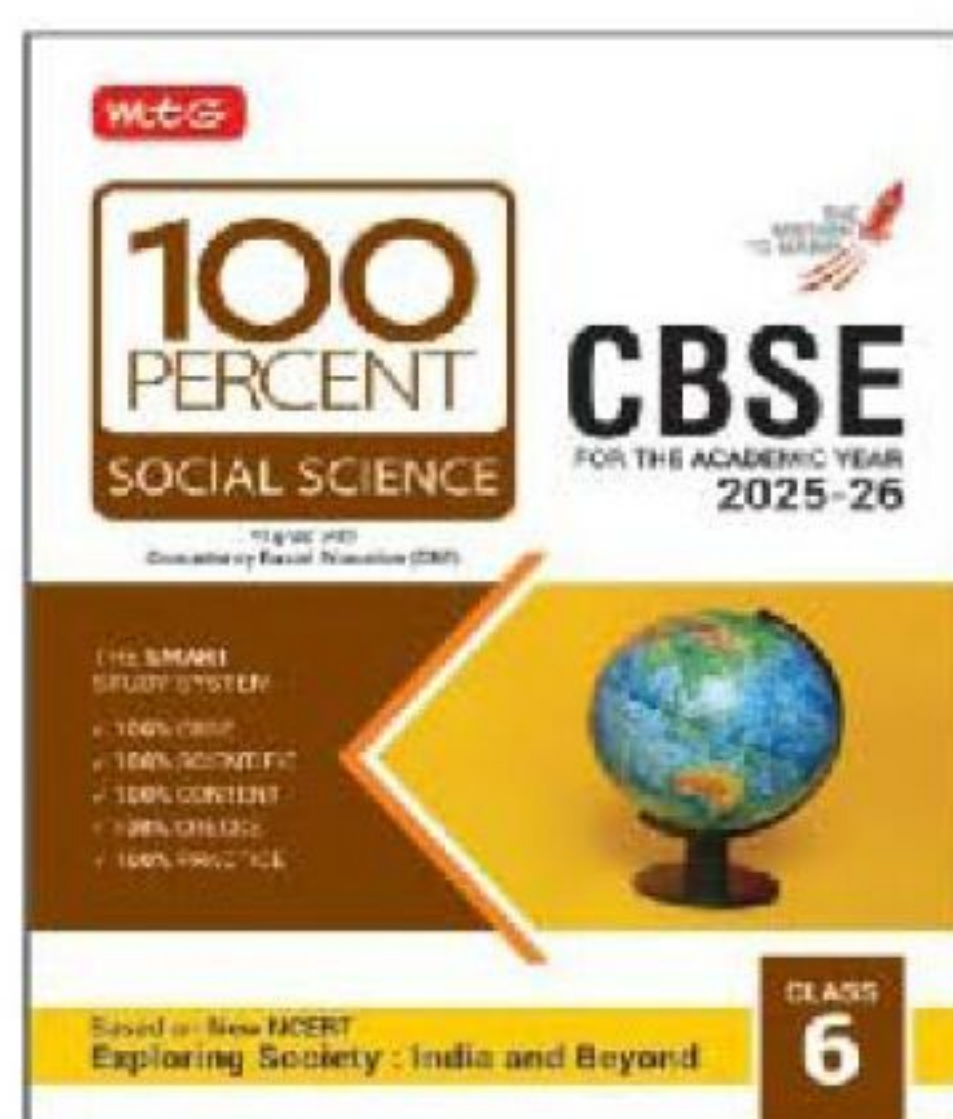
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Applications
must reach us by
**August 30,
2025.**

THE WORLD'S BIGGEST OLYMPIADS 2025-26



Girl Child
Scholarship
Scheme



Defence Services
Academic excellence
Scholarship



Academic
Excellence
Scholarship

₹ 24 Crores
Total Scholarships & Awards*

Gold Medals of
Excellence to top
10% in class*

S A P R
SCHOOL ACADEMIC PROGRESS REPORT
SAPR for all schools
SPR for all students



SOF INTERNATIONAL GENERAL
KNOWLEDGE OLYMPIAD



SOF INTERNATIONAL ENGLISH
OLYMPIAD



SOF NATIONAL SCIENCE
OLYMPIAD



SOF INTERNATIONAL
MATHEMATICS OLYMPIAD



SOF INTERNATIONAL
COMPUTER SCIENCE OLYMPIAD



SOF INTERNATIONAL
SOCIAL STUDIES OLYMPIAD



SOF INTERNATIONAL HINDI
OLYMPIAD



SOF INTERNATIONAL
COMMERCE OLYMPIAD

**THE WORLD'S
BIGGEST
OLYMPIADS**

96,499+
Schools

72
Countries

7.2+ Crores
Assessments

8
Olympiads

*T&C apply, please refer to prospectus and website.

For Details: Check with your teacher

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